NORTH CAROLINA

DEPARTMENT OF CONSERVATION AND DEVELOPMENT

DAN E. STEWART, *Director*

DIVISION OF MINERAL RESOURCES

STEPHEN G. CONRAD, *State Geologist*

BULLETIN 80

Pyrophyllite Deposits
in North Carolina

by

Jasper L. Stuckey

RALEIGH

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LETTER OF TRANSMITTAL

Raleigh, North Carolina
March 1, 1967

To His Excellency, HONORABLE DAN K. MOORE
Governor of North Carolina

Sir:

I have the honor to submit herewith manuscript for publication as Bulletin 80, "Pyrophyllite Deposits in North Carolina," by Jasper L. Stuckey.

This report contains detailed information on the occurrence, distribution and geology of pyrophyllite in North Carolina and should prove to be of considerable value to those interested in the mining and processing of this valuable mineral resource.

Respectfully submitted,

DAN E. STEWART
Director

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Pyrophyllite Deposits of North Carolina

By

Jasper L. Stuckey

ABSTRACT

All the known occurrences of pyrophyllite in North Carolina are found in Granville, Orange, Alamance, Chatham, Randolph, Moore and Montgomery counties where they are associated with volcanic-sedimentary rocks of the Carolina Slate Belt. These rocks consist of lava flows interbedded with beds of ash, tuff, breccia and shale or slate that vary in composition from rhyolitic, or acid, to andesitic, or basic, and fall into three natural groups: Felsic Volcanics, Mafic Volcanics, and Bedded Argillites (Volcanic Slate). They have been folded, faulted and metamorphosed to the extent that they contain a well defined cleavage that strikes northeast and dips, in general, to the northwest.

The pyrophyllite deposits which are irregular, oval or lens-like in form occur in acid volcanic rocks that vary from rhyolite to dacite in composition. The field, microscopic and chemical evidence indicates that the pyrophyllite bodies were formed by metasomatic replacement of the host rocks through the agency of hydrothermal solutions under conditions of intermediate temperature and pressure.

Pyrophyllite has a variety of uses chief of which are in paints, rubber goods, roofing materials, ceramic products and insecticides. Reserves, while not large, are ample for several years.

INTRODUCTION

The pyrophyllite deposits of North Carolina are associated with volcanic-sedimentary rocks of the Carolina Slate Belt. Volcanic-sedimentary and similar rocks form a belt or zone along the eastern border of the Piedmont Plateau and parts of the Coastal Plain all the way from the vicinity of Petersburg and Farmville, Virginia, southwest across North Carolina, South Carolina and into Georgia, as far as the southern part of Baldwin County south of Milledgeville—a total distance of over 400 miles. In North Carolina the zone occupied by volcanic-sedimentary rocks is known as the Carolina Slate Belt. It is in this belt that the pyrophyllite deposits of the state are found.

The western border of the Carolina Slate Belt lies a few miles east of Charlotte, Lexington and Thomasville, crosses Guilford County southeast of Greensboro and continues northeast across the northwest corner of Alamance and Orange counties and the center of Person County to the Virginia line. The eastern limits of this belt are marked by the cover of Coastal Plain sediments.

PREVIOUS WORK

Due to the presence of a wide variety of minerals in them, the rocks of the Carolina Slate Belt have been of interest for approximately 150 years. These rocks, because of their complex character and well developed cleavage, were called slates by a number of investigators over a period of 70 years before their true nature began to be recognized. The first published report on that part of the slate belt in which pyrophyllite deposits are known to occur was a descriptive list of rocks and minerals from North Carolina by Denison Olmsted (1822). In this list he described novaculite, slate, hornstone, whetstone and talc and soapstone from several counties including Orange and Chatham. He stated that the talc and soapstone were extensively used for building and ornamental purposes and added that Indian utensils of the same materials were common.

In 1823, Olmsted was appointed by the Board of Agriculture to make a geological survey of the State. In his first report (1825) he called attention to the "Great Slate Formation which passes quite across the State from northeast to southwest covering more or less of the counties of Person, Orange, Chatham, Montgomery ---." The presence of talc and soapstone was noted in Orange, Chatham and other counties together with beds of porphyry in the eastern part of the formation and bands of breccia consisting of rolled pebbles interbedded in a ferruginous greenstone in different places.

Ebenezer Emmons (1856), one of the most competent geologists of his time, considered the

Carolina Slate Belt rocks to be among the oldest in the country and placed them in his Taconic system which he divided into an upper and lower member. The upper member consisted of clay slates, chloritic sandstones, cherty beds and brecciated conglomerate. The lower member consisted of talcose slates, white and brown quartzites and conglomerate. He did not recognize the presence of volcanic rocks in what is now known as the Carolina Slate Belt. In his lower unit, Emmons found what he considered to be fossils and named them *Paleotrochis major* and *Paleotrochis minor*. Diller (1899) recognized these as spherulites in rhyolite.

Emmons described in some detail the phyrophyllite deposits near Glendon, Moore County, then known as Hancock's Mill and classed the talcose slates, or those containing the pyrophyllite, as the basal member or oldest rocks of his Taconic system. He further pointed out that pyrophyllite occurred in the same position in Montgomery County.

Prior to this time the pyrophyllite had been considered as soapstone, but Emmons tested it before the blowpipe and found it to contain aluminum and classed it as agalmatolite. He gave the physical properties of this mineral together with its uses and the methods of mining near Hancock's Mill. Brush (1862) analyzed some of the material from Hancock's Mill, Moore County and showed it to be pyrophyllite.

Kerr (1875) placed the rocks of the slate belt in the Huronian, which in his classification is a division of the Archean and considered them to be sedimentary. He mentioned talc and soapstone from Orange and Chatham counties but added nothing to the description already published by Emmons.

Kerr and Hanna (1893) in "Ores of North Carolina," described some old gold mines in the Deep River region and stated: "It is worthwhile to add that part of what passes for talc is pyrophyllite and even hydromicaceous."

Williams (1894) recognized for the first time the occurrence of ancient acid volcanic rocks in the slate belt. He studied a small area in Chatham County and applied for the first time modern petrographic methods to the study of these rocks. He described this area in part as follows: "Here are to be seen admirable exposures of volcanic flows and breccias with finer tuff deposits which have been sheared into slates by dynamic agencies." He classed the slate belt rocks as Precambrian in age.

Nitze and Hanna (1896) first used the name Carolina Slate Belt for the rocks Olmsted (1825) had designated the "Great Slate Formation." They recognized the occurrence of volcanic rocks in the slate belt and suggested that there had been more than one volcanic outbreak and during at least one period of inactivity slates had been deposited. They did not mention pyrophyllite but described in some detail the Bell, Burns and Cagle gold mines, all of which are in the pyrophyllite area along Deep River in Moore County and pointed out that there had been much silicification at all of these and some propylitic alteration at the Bell mine in particular.

Pratt (1900) described the pyrophyllite deposits near Glendon and showed by chemical analysis that the mineral is true pyrophyllite. He described the pyrophyllite deposits as follows: "They are associated with the slates of this region but are not in direct contact with them, being usually separated by bands of siliceous and iron breccia which are probably 100 to 150 feet thick. These bands contain more or less pyrophyllite and they merge into a stratum of pyrophyllite schists." He offered no suggestion as to the origin of either the slates, breccia or pyrophyllite.

Weed and Watson (1906) in a report on "The Virgilina Copper District," concluded that the rocks of that area were Precambrian volcanics, chiefly an original andesite that had been greatly altered by pressure and chemical metamorphism.

Laney (1910) presented a report on the "Gold Hill Mining District of North Carolina," in which he stated: "The rocks here included under the general term slates while having many local variations seem clearly to represent a great sedimentary series of shales with which are interbedded volcanic flows, breccias and tuffs. In their fresh and massive condition the slates are dense, bluish rocks which show in many places well defined bedding planes and laminations. The volcanic flows, breccias and tuffs which are interbedded with the slates apparently represent two kinds of lava, a rhyolitic and an andesitic type."

Pogue (1910) presented a report on the "Cid Mining District of Davidson County," in which he described the rocks of that area as follows: "Wide bands of sedimentary, slate-like rock, composed of varying admixtures of volcanic ash and land waste have the greatest areal extents. Intercalated with these occur strips and lenses of acid

and basic volcanic rocks, represented by fine and coarse-grained volcanic ejecta and old lava flows."

Laney (1917) in a report on the Virgilina district classed the rocks in the area studied as volcanic-sedimentary and stated: "Under this group are placed both the acid and basic flows and tuffs and the water laid tuffs and slates."

Stuckey (1928) presented a report on the Deep River region of Moore County in which he divided the rocks of the Carolina Slate Belt in that area into slates, acid tuffs, rhyolites, volcanic breccias and andesite flows and tuffs. He noted that the schistosity dipped to the northwest and interpreted the structure as a closely compressed synclinorium with axes of the folds parallel to the strike of the formations. In addition, he pointed out that metamorphism is not uniform throughout the area.

Bowman (1954) studied the structure of the Carolina Slate Belt near Albemarle, North Carolina, and recognized sedimentary rocks, volcanic tuffs and flows, and mafic intrusives in the area. He interpreted the structure as a series of undulating open folds.

Conley (1959); Stromquist and Conley, 1959; and Conley (1962 b) divided the rocks in the Albemarle and Denton 15-minute quadrangles into (1) a lower volcanic sequence consisting largely of felsic tuffs that have been folded into an anticline plunging to the southwest, (2) a volcanic-sedimentary sequence consisting of a lower argillite unit, an intermediate tuffaceous argillite unit and an upper graywacke unit which have been folded into a syncline also plunging to the southwest and (3) an upper volcanic sequence consisting of mafic and felsic volcanic rocks which unconformably overlie the first two sequences.

According to Conley (1962 a), "In Moore County only the lower and middle units appear to be present; however, some rhyolite in the area might belong to the upper unit. The exact stratigraphic relationships of some of the rocks in the county are in doubt because of the gradational nature of the contacts, a condition further complicated by intense folding and faulting and lack of outcrops."

Conley and Bain (1965) suggested that the rocks of the Carolina Slate Belt in North Carolina can be divided into natural, mappable rock units. They proposed and named a set of rock units or formations into which these rocks might be divided, gave their areal extent and described their structure and lithology. From oldest to youngest these proposed formations are:

Morrow Mountain rhyolite	
Badin greenstone	Tater Top Group
Unconformity	
Yadkin graywacke	
McManus formation	
Tillery formation	Albemarle Group
Efland formation	
Uwharrie formation	

The Uwharrie formation is composed chiefly of subaerially deposited felsic pyroclastic rocks. These are felsic tuffs consisting of interbedded lithic, lithic-crystal and devitrified vitric-crystal tuffs, welded flow tuffs and rhyolite.

The Efland formation is a water-laid sequence consisting of andesitic tuffs with interbedded greenstones, conglomerates, graywackes and flows.

The Albemarle Group is a water-laid sequence of pyroclastics and sediments which is divided into the Tillery formation, the McManus formation and the Yadkin graywacke.

The Tillery formation is composed in part of finely laminated argillite exhibiting graded bedding and in part of andesitic tuff and greenstone.

The McManus formation is predominantly a felsic tuffaceous argillite formerly known as the Monroe slate.

The Yadkin graywacke is a dark-green graywacke sandstone containing interbeds of mafic tuffaceous argillite, mafic lithic-crystal tuff and felsic lithic tuff.

The older rocks are in part unconformably overlain by subaerially deposited pyroclastics and flows known as the Tater Top Group. From base to top the group is composed of basaltic tuffs and flows overlain by rhyolite flows. The Tater Top Group is divided into the Badin greenstone and Morrow Mountain rhyolite.

The Badin greenstone is composed of lithic crystal tuffs and a basal unit of flows and flow tuffs of andesitic composition.

The Morrow Mountain rhyolite consists of dark-gray to black porphyritic rhyolite containing prominent flow banding.

Conley and Bain described the Troy anticlinorium, with a northeast-southwest trend, as the major structural feature of the Carolina Slate belt. West and southwest of the Troy anticlinori-

um, northeast trending open folded synclines and anticlines predominate. East of the Troy anticlinorium the rocks are more intensely folded. They are compressed into northeast trending asymmetric folds whose axial planes usually dip steeply to the northwest. In many places, argillite has been converted into slate and phyllite.

They considered the age of Carolina Slate Belt rocks to be early Paleozoic.

GEOLOGY OF THE CAROLINA SLATE BELT

GENERAL STATEMENT

In North Carolina rocks of the Carolina Slate Belt actually form two belts that are separated by sedimentary rocks of the Durham, Deep River and Wadesboro Triassic basins and by the Rolesville granite pluton and associated gneisses and schists. The first and most important of these and the one Olmsted (1825) first called the "Great Slate Formation" and Nitze and Hanna (1896) first called the Carolina Slate Belt lies to the west of the belt of Triassic rocks and varies in width from 20 to 60 miles. It is widest between Sanford and Lexington and narrows to the north and south. It crosses the central part of the State in a northeast-southwest direction from Anson and Union counties on the southwest to Granville, Person and Vance counties on the northeast and underlies all or parts of Anson, Union, Mecklenburg, Cabarrus, Stanly, Montgomery, Moore, Chatham, Randolph, Davidson, Rowan, Guilford, Alamance, Orange, Durham, Person, Granville and Vance counties. This belt contains all the known pyrophyllite deposits in North Carolina and will be considered in detail below.

The second belt in which Kerr (1875) first recognized metavolcanic rocks lies to the east of the belts of Triassic, igneous and metamorphic rocks. It begins in Anson County on the south, varies greatly in width and regularity and continues in a northeast direction to Northampton County on the north. It is exposed at the surface in all or parts of Anson, Richmond, Moore, Harnett, Lee, Wake, Johnston, Wayne, Wilson, Franklin, Nash, Halifax and Northampton counties.

The eastern limits of this belt are unknown due to the cover of Coastal Plain sediments. A deep well in Camden County about 8 miles north of Elizabeth City, the county seat of Pasquotank County, penetrated rocks that are apparently of the Carolina Slate Belt. Two deep wells—one a few miles southeast of Kelly, Bladen County and the other 4 miles south of Atkinson, Pender County—both penetrated Carolina Slate Belt rocks. West of a line from Elizabeth City to Atkinson, of the few wells that reached basement, some penetrated granite, some penetrated gneiss and schist and a few penetrated rocks of the Carolina Slate Belt.

It is possible that if the crystalline floor beneath Coastal Plains sediments was exposed, the types and percentages of rocks in this floor would not differ greatly from those found west of Coastal Plain sediments in Harnett, Johnston, Wake, Wilson, Franklin, Nash, Vance, Warren, Halifax and Northampton counties, where gneisses and schists, granites and rocks of the Carolina Slate Belt occur in about equal amounts.

Pyrophyllite has not been found in this eastern zone of Carolina Slate Belt rocks and they are not considered further in this report.

DISTRIBUTION AND CHARACTER OF THE ROCKS

The rocks of the Carolina Slate Belt, west of the Durham, Deep River, and Wadesboro Triassic basins, consist of lava flows interbedded with beds of ash, tuff, breccia and shale or slate. All of these except the flows contain much nonvolcanic material in the form of mud, clay, silt, sand and conglomerate. (Also present is much nondescript material, some of which may be volcanic, which for the lack of a better term has been designated land waste). The flows, breccias, tuffs and ash beds and beds of shale or slate are all interbedded and in general do not appear to occupy definite stratigraphic positions in the series. The flows vary from rhyolite through andesite to basalt. The rhyolites and andesites vary from fine grained to coarsely porphyritic whereas the basalts are often amygdaloidal. The breccias vary from rhyolitic to andesitic in composition and in fragment size from one-half inch to nearly a foot in diameter. The fragments of the breccias are in turn fragmental, apparently pyroclastic in origin. Some of the fragments in the breccias are sharply angular, although many are rounded, indicating transportation and deposition. The tuffs, while containing both acid and basic materials, are in general of an acid composition and composed of fragments less than half an inch in diameter. These fragments which

vary from angular to rounded are often embedded in much fine-grained material apparently of non-volcanic origin.

Beginning in the vicinity of the Randolph-Chatham county line, 15 to 20 miles south of Siler City, and continuing northeast through Siler City to the northern part of Orange County and the southeastern part of Person County are a number of beds of quartz conglomerate varying in width from a few inches to as much as 250 feet and of unknown length. The quartz pebbles in this conglomerate are generally less than an inch in diameter, well rounded and embedded in silt and sand, further indicating sedimentary processes.

The shales and slates, which are generally well bedded, are composed of fine-grained volcanic materials (and much land waste) in the form of clay, silt and fine sand. Finally, much of the fine-grained materials in the breccias, tuffs and portions of the shales and slates strongly resemble metasiltstone and metagraywacke of some of the metagraywacke rocks in other areas, further indicating sedimentary processes.

A wide variety of rocks are present in the Carolina Slate Belt and various attempts have been made to divide them into units or formations. Conley (1959) and Stromquist and Conley (1959) proposed a three fold division of the rocks of the Albemarle and Denton 15-minute quadrangles, while Conley and Bain (1965) proposed a set of nomenclature for the rock-stratigraphic units and their areal extent in the Carolina Slate Belt. Since these proposals are not well known and generally accepted and since the rocks of the Carolina Slate Belt fall into three natural divisions, it appears that these three natural divisions are to be preferred in this discussion. These three divisions are Felsic volcanic rocks, Mafic volcanic rocks and Bedded argillites (volcanic slate).

FELSIC VOLCANIC ROCKS

Felsic volcanic rocks occupy about half of the Carolina Slate Belt in the central part of the State and are the predominating rocks in the eastern part of the Piedmont Plateau. In this area they occupy much of the Carolina Slate Belt west of the Durham and Deep River Triassic basins and northeast of Anson, Union and Stanly counties.

The felsic volcanic rocks consist largely of materials of volcanic flow or fragmental origin. The flows are essentially rhyolite, while the fragmental materials vary from rhyolitic to dacitic in composition. The fragmental rocks consist of breccias and coarse and fine tuffs, with coarse and fine tuffs making up the greater portion of the occurrences. Lenses of mafic volcanics and bedded slate of limited extent are also present.

The fragmental rocks consist of fine and coarse tuffs and breccias. The coarse tuffs predominate and contain the fine tuffs and breccias as interbedded bands and lenses. The fragments composing these rocks are angular to well rounded and vary in size from nearly a foot to a fraction of an inch in diameter.

The fine tuff occurs interbedded with both the slate and coarse tuff and grades into each of them. It has no wide areal extent but occurs as narrow bands and lenses in the coarse tuffs.

Microscopically the fine tuff shows a cryptocrystalline ground mass with fragments of quartz and feldspar (orthoclase, albite, oligoclase) as well as secondary minerals epidote, clinozoisite, chlorite and calcite. Iron oxides are sparingly present. Some sections show small rock fragments containing original flow structure while others exhibit a parallel arrangement of the particles due to metamorphism.

The coarse tuff varies from a massive to a highly schistose type of rock, that in places has been so slightly changed as to show some of its original characters. There is every gradation to a fine tuff on one hand and to a breccia on the other. The freshly broken rock proves to be made up of quartz and feldspar grains and rock fragments of less than one-half an inch in diameter set in a bluish or greenish-gray groundmass, the whole often resembling an arkose.

In thin section the coarse tuff shows fragmental phenocrysts of quartz, orthoclase and acid plagioclase with fragments of different kinds of rocks, some of which show definite flow structure, all embedded in a fine-grained groundmass. Kaolinite, epidote and calcite form secondary products. Biotite and muscovite are rare. Grains of hematite and limonite as well as small particles of titanite and apatite are found in most sections.

Flows of rhyolite occur as narrow bands and lenses in the tuff into which they appear to grade at places. This apparent gradation is possibly due to the fact that some material classed as silicified

fine tuff may be partially devitrified rhyolite. The rhyolite is dense and indistinctly porphyritic, with a dark gray to bluish color, and in fresh fracture shows a greasy luster. Flow lines have developed in numerous places and are best seen on weathered surfaces, while amygdaloidal structure may be found in a number of outcrops.

In thin section the rhyolite shows phenocrysts of plagioclase (chiefly oligoclase) orthoclase and quartz, named in the order of relative abundance. Kaolinite, epidote and chlorite have developed commonly from the weathering of the feldspars, and calcite is frequently found along fractures in the rocks.

Acid volcanic breccia includes all felsic rocks that exhibit a fragmental character sufficiently well defined to attract attention in the hand specimen, and in which the fragments are over one-half inch in diameter. The size of the fragments (observed) varies from one-half inch to several inches in diameter. These rocks consist partly of brecciated tuff and partly of brecciated rhyolite. When freshly broken the breccia often shows a greenish or mottled-gray color, produced by various colored fragments in a finer groundmass. In places the breccia has been strongly sheared and it nearly always shows some mashing and schistosity, but on the whole is more massive than the finer tuff rocks.

Thin sections show little difference from the regular coarse tuffs. The fragments are chiefly of tuffaceous or rhyolitic character with occasional slate fragments. Phenocrysts of quartz, orthoclase and plagioclase (chiefly oligoclase) are abundant. The fragments of the brecciated rhyolite phase show a flow structure. In all phases of the breccia the groundmass is altered and kaolinized. Grains of iron oxide chiefly hematite are present, while the secondary minerals epidote and calcite and secondary quartz are plentiful.

MAFIC VOLCANIC ROCKS

Mafic volcanic rocks are scattered throughout the northern two thirds of the Carolina Slate Belt, but are most abundant along the western side. The rocks of this unit consist of volcanic fragmental and flow materials. The fragmental materials are chiefly normal tuffs and breccias of andesitic composition, while the flows vary from andesite to basalt.

The tuffs are generally andesitic in composition. In places they are fine grained and lack the fragmental appearance. In such areas, one of which may be seen along U.S. Highway 64, for a mile west of Haw River in Chatham County, the rock strongly resembles a graywacke. The tuffs contain much epidote and often have a greenish color. Other colors vary from dark gray to nearly black. In addition to epidote, plagioclase, quartz and secondary calcite, iron oxides are present. The mafic fragmental rocks are not as strongly metamorphosed as the felsic fragmental rocks, but contain a cleavage that strikes northeast and dips northwest in the southern part of the area and to the southeast in the northern part.

The mafic breccia is distinctly more basic than the felsic breccias and appears to be mainly andesitic in composition. It consists chiefly of brecciated tuffs and flows, but ranges all the way from a fine and highly mashed tuff to a massive coarse breccia with fragments up to several inches in diameter. It varies from a dark gray through a chlorite and epidote green color.

In thin section this rock appears more uniform than in the hand specimen. Fragmental materials embedded in a feldspathic groundmass make up most of the rock. The following minerals are present: orthoclase, plagioclase (oligoclase and andesine) chlorite, epidote, zoisite, clinozoisite, quartz, calcite, iron oxides, kaolinite and sericite.

The andesite and basalt occur as bands and lenses interbedded with the fragmentals. The andesite is dark green in color, usually massive or fine grained, but occasionally coarsely porphyritic. A coarse porphyritic variety, with hornblende crystals up to two inches long occurs in western Randolph County. The basalt is dark to nearly black and often amygdaloidal. Both the andesite and the basalt are characterized by the lack of a well defined cleavage. The minerals present include epidote, plagioclase, quartz, secondary calcite and iron oxides. Epidote is the most abundant mineral present, giving the rock its green color. The name greenstone is often used for this rock.

BEDDED ARGILLITES (VOLCANIC SLATE)

Bedded argillites (volcanic slate) commonly referred to as slate, bedded slate, or volcanic slate, occur in the southern part of the Carolina Slate Belt and extend as far north as the central part of Davidson and Randolph counties. A few small areas occur on the east side of the belt in Montgomery, Moore and Chatham counties. There

are, also, some small areas east of the Jonesboro fault in Anson and Richmond counties.

The bedded argillites (volcanic slate) consist chiefly of dark colored or bluish shales or slates, which are usually massive and thick bedded. However, the beds occasionally show very finely marked bedding planes. Contacts between the slates and tuffs are usually gradational and often a single hand specimen will show gradation from a bedded slate to a fine-grained tuff. In composition the bedded argillites vary from felsic tuffaceous argillite to mafic tuffaceous argillite intermixed with varying amounts of weathered material and land waste. Much of the slate is massive and jointed showing little effects of metamorphism while in other places it has been strongly metamorphosed and shows a well defined slaty cleavage. The cleavage or schistosity does not in most places correspond to the bedding planes of the rock. In places, especially near igneous intrusives and mineralized zones, the slate is often highly silicified and resembles chert.

IGNEOUS INTRUSIVE ROCKS

The Carolina Slate Belt is bordered on the west by an igneous complex composed of gabbro, diorite and granite and intruded at many places, particularly in the northern half by granitic-type rocks. These igneous intrusives apparently vary from late Ordovician to early Permian in age.

ENVIRONMENT OF DEPOSITION

The occurrence of volcanic-sedimentary rocks along the western edge of the Coastal Plain and eastern edge of the Piedmont Plateau, in a long narrow belt that extends from southeastern Virginia to central Georgia, with a length of more than 400 miles and width up to 120 miles, suggests deposition under geosynclinal conditions. As indicated above, these rocks consist of a great volcanic-sedimentary series varying from felsic to mafic in composition and composed of lava flows, beds of breccia, coarse tuff, fine tuff and ash, and beds of shale or slate now designated as bedded slates or argillites. The lava flows and the coarse angular tuff and breccias could have been formed on land or under water. Conclusive evidence for one as opposed to the other is lacking. Many of the tuffs and breccias consist largely of subangular to rounded fragments that were certainly reworked and deposited in water. The bedded slates and argillites were definitely water laid. Their composition, both chemical and physical, and their texture indicate that they were not transported great distances. Finally, the presence of varying amounts of nonvolcanic materials or land waste in the form of mud, clay, silt, sand and at places rounded quartz pebbles up to an inch in diameter indicate that varying amounts of materials were brought into the area from adjacent land masses.

There seems to be little doubt that the rocks of the Carolina Slate Belt were formed in a eugeosyncline. The volcanic materials in this geosyncline came largely from beneath the surface by volcanic eruptions, while the nonvolcanic sediments came from narrow belts of uplift that were present in or adjacent to the trough.

The thickness of these rocks is variable but unknown. It appears possible, however, that in central North Carolina, west of the Durham, Deep River and Wadesboro Triassic basins, the volcanic-sedimentary series may have a thickness up to 20,000 or 30,000 feet. The period of volcanic-activity during which this great series of volcanic-sedimentary rocks were being formed must have continued through a very long time, perhaps hundreds of thousands or even millions of years. During this time, there were innumerable alternations between quiet upwelling of lava, explosive activity piling up great amounts of tuff, breccia and ash and periods of comparative quiet accompanied by weathering, erosion and deposition of the bedded deposits. Between successive outbursts the magma probably underwent some degree of differentiation so as to give rise to more acid rocks at one time and more basic at another. Such changes were not great for at no time did the products depart far from the general type which was a relative acid magma rich in soda.

STRUCTURAL FEATURES

The chief structural features of the rocks of the Carolina Slate Belt are cleavage planes, joints, folds and faults. The first of these to be of interest was the cleavage planes. Olmsted (1825) designated these rocks as the Great Slate Formation because of the well developed, slate-like cleavage which he observed over most of the area. In general, rocks of the Carolina Slate Belt south of U.S. Highway 70 from Durham to Greensboro have a well defined cleavage that

strikes northeast and dips steeply to the northwest. North of this line the cleavage continues to strike northeast but much of the dip is to the southeast and at a lower angle than that which dips to the northwest. No explanation for this change in dip is readily available.

The metamorphism which produced the cleavage was not as intense as was originally thought and also varied widely from place to place. At places, metamorphism was so severe that the cleavage has become schistosity and the rocks are essentially schists. At other places, the cleavage apparently grades into jointing. As a result, the massive rocks are highly jointed and contain poorly developed cleavage planes.

Recent work has revealed that folding is better developed than was formerly thought. It is now established that the rocks are in general well folded into a series of anticlines and synclines. The largest and most important fold is the Troy anticlinorium which trends in a northeast-southwest direction and whose axis lies a short distance west of Troy. West and southwest of the Troy anticlinorium, northeast-trending open folded synclines and anticlines predominate. The most important of these is the New London syncline. East, southeast, and northeast of the Troy anticlinorium the intensity of the folding increases. The rocks are tightly compressed into northeast-trending, asymmetric folds whose axial planes usually dip steeply to the northwest.

The bedded argillites (volcanic slate) seem to have consolidated readily and folded like normal sediments while the tuffs and breccias remained in a state of open texture and tended to mash and shear instead of folding. This is indicated by the mashed and sheared condition of practically all the tuffs while in numerous cases more or less well preserved bedding planes in the slates indicate definite folding.

Numerous insignificant faults occur in nearly all parts of the Carolina Slate Belt. These in general never amount to more than a few feet and are doubtless only the adjustments due to the folding of the rocks and are not of any great structural importance. However, along the eastern border of the belt where the Carolina Slate Belt rocks have been compressed into northeast-trending asymmetric folds whose axial planes dip steeply to the northwest, thrust faults are present. The abundance and importance of these faults in relation to the overall structure of the Carolina Slate Belt are not yet fully established, but recent geologic mapping has revealed the presence of such faults in Moore and Orange counties.

AGE OF THE ROCKS

Emmons (1856), the first worker to date the rocks of the Carolina Slate Belt, considered them to be mainly slates and quartzites of sedimentary origin as shown by the presence of rounded pebbles. He divided these rocks into a lower and upper series and placed them in his Taconic system which was early Paleozoic in age. He considered the talcose slates of the lower series to have essentially the same composition as the underlying primary series and stated: "The talcose slates may be regarded as the bottom rocks, the oldest sediments which can be recognized, and in which, probably, no organic remains will be found."

Later Emmons found near Troy, Montgomery County, two or three species of fossils in the lower series of the Taconic system. These fossils, which belonged to the class of zoophites, the lowest organisms of the animal kingdom, were found through about 1000 feet of rock and occurred from a few in number to abundant.

The fossils were considered to be corals of a lenticular form that varied in size from a small pea to two inches in diameter. At first, Emmons considered the difference between the small and the larger forms to be the result of age but later decided that they were specific and named the small form *Paleotrochis minor* and the large form *Paleotrochis major*.

These forms were of interest to Emmons mainly in showing that lower Taconic rocks were fossiliferous rather than in actually dating the rocks. *Paleotrochis major* and *Paleotrochis minor* were later identified as spherulites in rhyolite and not fossils, Diller (1899).

Kerr (1875) classed the rocks of the Carolina Slate Belt as Huronian in age, which in his classification is a division of the Archean. Williams (1894) classed them as Precambrian in age. Watson and Powell (1911) on the basis of fossils, considered the Arvonia slates of the Piedmont of Virginia to be Ordovician in age. Laney (1917) on the basis of the work by Watson and Powell, classed the volcanic-sedimentary rocks of the Virgilina district of the Carolina Slate Belt as Ordovician in age.

In recent years the trend has been to place the age of these rocks as early Paleozoic, probably

Ordovician. According to the U.S. Geological Survey, Professional Paper 450A, Research 1962, "Lead-alpha measurements by T. W. Stern on zircon collected by A. A. Stromquist and A. M. White from felsic crystal tuffs in the Volcanic Slate belt of the central North Carolina piedmont have confirmed a previously inferred Ordovician age for these unfossiliferous rocks." White, et. al. (1963) gave the details on the collection and evaluation of two samples of zircon from the Albemarle quadrangle and stated: ". . . the indicated age for each is Ordovician according to Holmes time scale (Holmes, 1959, p. 204)."

Recently, St. Jean (1964) reported the first authentic discovery of fossils in the Carolina Slate Belt of North Carolina. The discovery consisted of two abraded and moderately distorted thoraxes and pygidia of a new trilobite species. The specimens were collected from a piece of stream rubble in Island Creek at Stanly County Road 1115. The type rock in which the fossils occurred is present in outcrops upstream. St. Jean classed the specimens as a new species questionably assigned to the Middle Cambrian genus *Paradoxides* and stated: "Although the generic assignment is questionable, the morphologic characters of the two specimens indicate an age no younger than Middle Cambrian and no older than the age of the oldest known Early Cambrian trilobites."

"The specimens are significant because they represent the first authentic fossil material from the Piedmont south of Virginia and provide paleontological documentation of the age and marine nature of a lithologic unit in the area. Micropygous Cambrian trilobites are more common in eugeosynclinal belts, which part is in keeping with the paleogeographic and lithologic setting."

Granites of post-Ordovician but Paleozoic age and diabase dikes of Triassic age both intrude the Carolina Slate Belt rocks. The granites apparently furnished the solutions that produced the pyrophyllite and associated minerals, and are considered further below. The diabase dikes have no relations to the pyrophyllite deposits and are not discussed further.

GEOLOGY OF THE PYROPHYLLITE DEPOSITS

INTRODUCTION

Just when pyrophyllite was first discovered in North Carolina is not known. Olmsted (1822) in a report entitled, "Descriptive Catalogue of Rocks and Minerals Collected in North Carolina" listed talc and soapstone from several counties including Chatham and Orange and stated that they were extensively used for building and ornamental purposes, and added that Indian utensils of the same materials were common. In 1825 he called attention to the "Great Slate Formation" which passes across the State from northeast to southwest and again noted the presence of talc and soapstone in Chatham and Orange counties. Since no talc and soapstone are known to occur in rocks of the Carolina Slate Belt and since pyrophyllite is found at a number of localities in the belt it is quite probable that the deposits mentioned by Olmsted were pyrophyllite.

Emmons (1856) described a material which was locally known as soapstone at Hancock's Mill, (Now Glendon) Moore County and near Troy, Montgomery as follows: "A rock, which occurs in extensive beds, and known in the localities where it is found as a soapstone, can by no means be placed properly with the magnesium minerals. It is white, slaty, or compact translucent, and has the common soapy feel of soapstone, and resembles it so closely to the eye and feel that it would pass in any market for this rock. It has, however, a finer texture, and is somewhat harder; but it may be scratched by the nail, so that it ranks with softest of minerals: it scratches talc, and is not itself scratched by it; it is infusible before the blowpipe, and with nitrate of cobalt gives an intensely blue color, proving thereby the presence of alumina in place of magnesia." He classed the mineral as agalmatolite, the figure stone of the Chinese, and described the methods used in quarrying it at Hancock's Mill.

Brush (1862) analyzed some of the material from Hancock's Mill, Moore County and showed it to be pyrophyllite.

Pratt (1900) described the deposits and published further analyses of the pyrophyllite. He stated that: "While the talc deposits of Cherokee and Swain counties are pockety in nature and of limited depth, the pyrophyllite formation is continuous and of considerable, though of unknown depth."

Pratt described the pyrophyllite as follows: "While possessing many of the physical properties of talc and often being mistaken for it, the pyrophyllite is quite different in its chemical composition, and is a distant mineral species. Although this mineral probably cannot be put to

all the uses of talc, it can be used for the larger number of them, and those for which the talc is used in the greatest quantity. Some of this might be of such quality that it could be cut into pencils, but the most of this mineral would only be of value when ground. It is soft with a greasy feel and pearly luster, and has a foliated structure. The color varies from green, greenish and yellowish-white to almost white; but when air-dried they all become nearly white. Very little compact pyrophyllite has been observed that would be suitable for carving, as is used in China, although considerable of this has been used in the manufacture of slate pencils."

Pratt presented three chemical analyses of pyrophyllite from Moore County that were very close to the theoretical composition of that mineral. He, also, pointed out that the deposits had been worked almost continuously since the Civil War.

Hafer (1913) noted that the pyrophyllite did not differ greatly from the sericite found in the old gold mines of the slate belt and may have originated in the same manner. He, also, called attention to the masses of pyrite-bearing quartz that are often found associated with the pyrophyllite deposits.

Stuckey (1928) presented the first detailed report of the pyrophyllite deposits of North Carolina. He described their distribution, geological setting, form or shape, mineralogy, origin and possible continuation with depth. He classed the deposits as hydrothermal in origin and thought that they might continue to considerable depths.

DISTRIBUTION

Pyrophyllite occurrences are known along the eastern half of the Carolina Slate Belt from the vicinity of Wadesville in the southwestern part of Montgomery County northeastward to the northern part of Granville County near the Virginia line. These occurrences may consist of a single deposit or they may contain several prospects or deposits.

In Montgomery County pyrophyllite is known to occur near Wadesville; on Cotton Stone Mountain, 3.5 miles north of Troy; just east of State Road 1312 near Abner; and northeast of Asbury in the northeastern corner of the county. Considerable prospecting has been done near Wadesville and the area appears promising for mining. Limited prospecting has been done on Cotton Stone Mountain but no mining has been carried out. Limited prospecting and some mining have been carried out on the deposit near Abner but the property is currently idle. One deposit northeast of Asbury appears to have been worked out, but another is promising for future development.

In Moore County, pyrophyllite is found approximately four miles southwest of Spies near the point where Cotton Creek enters Cabin Creek; near Robbins; and in a zone several miles long that lies along Deep River north of Glendon. The Robbins area contains the only underground mine, which is the largest pyrophyllite mine in the State, and several open pit prospects. The Glendon zone contains three active open cut mines and a number of prospects.

Pyrophyllite is known to occur in Randolph County in the vicinity of Pilot Mountain about 8 miles southeast of Asheboro, just north of State Highway 902, and near Staley in the northeastern part of the county. In the Pilot Mountain area there are four prospects, one of which has been explored and considerable iron-stained pyrophyllite is reported to be present. No mining has been carried out in this area. The deposit near Staley, which at one time contained the second largest mine in the State, has been worked out and abandoned.

The only known pyrophyllite area in Chatham County is located near the Chatham-Alamance county line on the Hinshaw property. This property is about 2 miles east of State Road 1004 and a short distance north of State Road 1343. Pyrophyllite crops out at three places in the area, one of which has been prospected to a limited extent. No mining is being carried out in the area.

Pyrophyllite is known to occur at two localities near Snow Camp in southern Alamance County. On Pine Mountain southeast of Snow Camp is a major open pit mine from which pyrophyllite has been mined for more than 20 years. About 2 miles east of Snow Camp there are several pyrophyllite exposures on a prominent hill known as Major Hill. Major Hill lies south of State Road 1005 and between State Roads 2356 and 2351. The outcrops in Major Hill are promising and prospecting is currently underway.

In Orange County pyrophyllite is known to occur in the vicinity of Teer in the southwestern part of the county; near Hillsborough; and on the Murray estate about 6 miles northeast of of Hillsborough. In the vicinity of Teer, prospecting has been carried out at three or more places

and limited mining was done at one time. This area has been abandoned at least temporarily. South and southwest of Hillsborough are three prominent hills which trend northeast and parallel the major geologic structure of the area. The northern most of these hills contains a major open cut pyrophyllite mine that is an important producer of pyrophyllite, andalusite, sericite and silica. The deposit in the Murray property northeast of Hillsborough lies south of State Road 1538 and west of State Road 1548. Considerable prospecting has been carried out on this property, but no mining has been done.

In Granville County, pyrophyllite deposits are found on Bowlings Mountain northwest of Stem; at several places on Long Mountain which lies to the northwest of Bowlings Mountain; and on Daniels Mountain about 9 miles north of Oxford. On Bowlings Mountain, which is located about three miles slightly northwest of Stem, prospecting and some mining have exposed a major pyrophyllite deposit. To the northwest of Bowlings Mountain is a northeast trending series of irregular hills that occupy an area a mile or more in width and some 4 miles long, known as Long Mountain. Prospecting and some exploration have demonstrated the presence of pyrophyllite at several places on Long Mountain, but no mining has been done. About 9 miles north of Oxford and 1.5 miles northeast of State Highway 96 and east of Mountain Creek is Daniels Mountain on which pyrophyllite is known to occur. No prospecting or mining has been done on this mountain.

GEOLOGIC RELATIONS

All the pyrophyllite deposits of North Carolina occur in acid volcanic rocks, chiefly in medium to fine-grained tuffs and to a less extent in an acid volcanic breccia. They are not found at any place in a basic andesitic type of rock or associated with a typical water-laid slate. At the Phillips, Womble and Reaves mines, which are found in the Deep River pyrophyllite zone north of Glendon, Moore County, the footwall side of the pyrophyllite bodies is an acid volcanic breccia. Next to the footwall is a highly mineralized pyrophyllite zone that grades into a fine-grained acid tuff. At places the pyrophyllite grades into and replaces parts of the brecciated footwall. Where the band of volcanic breccia is absent from the footwall side of the deposits, in this zone, the pyrophyllite bodies are much nearer the slate than where the breccia is present, but they are never found in normal slate. On the hanging wall side the pyrophyllite grades into medium to fine-grained acid tuff.

The geologic distribution of the pyrophyllite deposits is probably controlled in part by the composition of the rocks and in part by rock structures. As indicated above (page 8), the tuffs and breccias remained in a state of open texture and tended to mash and shear instead of folding. As a result, the acid tuffs and breccias developed shear zones along which the pyrophyllite mineralization was later concentrated. A few shear zones, particularly those along Deep River near Glendon and near Robbins (both in Moore County) were developed along major thrust faults. However, the great majority of the pyrophyllite deposits are found in shear zones that do not show any evidence of containing faults.

FORM AND STRUCTURE

A prominent feature of the pyrophyllite bodies is their irregular, oval, or lens-like form. This structure is observed along the strike and also vertically to the depths reached in mining. In nearly every deposit that has been developed enough to show the true structure, bodies and lenses of pyrophyllite are found along with lenses of tuffaceous rocks that exhibit various stages of alteration. Most pyrophyllite deposits occur as narrow bands or zones aligned with the cleavage strike and dip of the country rock. They range in size from those measured in inches up to 500 feet wide and 1500 to 2000 feet long. The strike of the cleavage in both the country rock and the pyrophyllite bodies is northeast-southwest, while the dip is steeply to the northwest.

In most cases the larger mineralized zones consist of a very siliceous footwall, a well developed mineralized zone and a highly siliceous and sericitic hanging wall. Where these conditions exist contacts between the mineralized zone and the footwall and the hanging wall are gradational. Contacts between the footwall and country rock and the hanging wall and country rocks are, also, gradational. When the siliceous footwall and the sericitic hanging wall are absent, as they frequently are, contacts between the mineralized zones and the country rocks are gradational.

Excellent examples of the siliceous footwall may be seen at the Bowlings Mountain deposit,

Granville County, at the Hillsborough deposit, Orange County, at the Staley deposit, Randolph County, and at the mine of the Standard Mineral Company, Moore County. In general, it consists of a light blue-gray to white, fine-grained to medium-grained rock having the general appearance of quartzite. Selected samples from the more massive portions of this rock consist almost entirely of silica. The rock has been fractured considerably at places and contains varying amounts of sericite and pyrophyllite. When fresh, the rock is hard and dense and breaks with a conchoidal fracture. When weathered, it breaks down to a sandy friable material that is usually white, but is often stained various shades of yellow and red by iron oxide.

The siliceous footwall ranges from less than 5 to more than 50 feet in thickness and in many cases extends the entire length of the deposit. When it occurs as a massive unit, it often crops out as bold ledges near the crest of the hill as at the Staley and Hillsborough deposits. However, as at the mine of the Standard Mineral Company near Robbins, Moore County, it may not crop out at all. From the footwall mineralization increases inward to rich zones and lenses of pyrophyllite and then decreases towards a schistose and sericitized hanging wall.

MINERALOGY OF THE DEPOSITS

The minerals most commonly observed in the pyrophyllite deposits in the apparent order of their abundance are pyrophyllite, quartz, sericite, chloritoid, pyrite, chlorite, feldspar, iron oxides, zircon, titanite, zeolites and apatite. Of these, only the first eight are present in important amounts or related to the development of the pyrophyllite. The other minerals are present in small amounts to the extent they might occur as accessory constituents of an igneous rock or as products of regional metamorphism or weathering.

In addition, small amounts of fluorite have been found with quartz veins intruding the fault zone at the Phillips mine. Also, varying amounts of the high-alumina minerals andalusite, diaspore, kyanite and topaz have been found in several pyrophyllite mines and prospects. The position of these high-alumina minerals in the mineral sequence of the pyrophyllite deposits is not clear and they are discussed below.

Pyrophyllite

Pyrophyllite is a hydrous aluminum silicate with the general formula $H_2Al_2Si_4O_{12}$. It crystallizes in the orthorhombic system, but good crystals are rare. It commonly occurs as (1) foliated, (2) granular and (3) radial or stellate masses. The color varies from nearly black through yellowish white, green, and apple green to pure white. It has a specific gravity of about 2.8 to 2.9, and a hardness less than the finger nail. It has a pearly luster, a greasy feel and commonly occurs as masses, lenses and pockets associated with quartz, sericite and chloritoid. The pyrophyllite in the deposits near Glendon and Robbins, Moore County, consists almost entirely of the foliated variety. That in the other major deposits consists largely of massive granular and radial fibrous forms with occasional small amounts of the foliated variety.

Quartz

Quartz is an oxide of silicon with the general formula SiO_2. It crystallizes in the hexagonal system, and good crystal specimens are common. Quartz is colorless when pure, has a conchoidal fracture, a viterous luster, a hardness of 7 and a specific gravity of 2.65. It is abundant throughout the deposits everywhere except in the very purest pyrophyllite and occurs (1) as large masses of cherty or milky appearance, (2) as clear veins and stringers in the deposits and along the walls, and (3) as small masses and nodules in the altered or only partly altered rock.

Sericite

Sericite is a fine-grained variety of mica, usually muscovite, occurring in small scales and having the composition $(H,K)AlSiO_4$. It crystallizes in the monoclinic system, has a basal cleavage, a hardness of 2-2.25, a specific gravity of 2.76-3 and a vitreous luster. The color varies from colorless through gray, pale green, and violet to rose-red. Sericite is often concentrated as bands or zones along the hanging wall of the pyrophyllite bodies and to a lesser extent along the footwall. It is, also, present as finely divided scales and flakes and as zones through good pyrophyllite.

Chloritoid

Chloritoid probably crystallizes in the triclinic system but rarely occurs in distinct tabular crys-

tals. It often occurs in the form of sheaves or rosettes. The general formula is $H_2(Fe,Mg)Al_2SiO_7$. It has a basal cleavage, a pearly luster, a hardness of 6.5 and a specific gravity of 3.52-3.57. The color varies from dark gray through greenish black to grayish black. Chloritoid is found in varying amounts in all the pyrophyllite deposits but is most abundant in those along Deep River north of Glendon, Moore County where an acid iron breccia forms part of the footwall.

Pyrite

Pyrite has the formula FeS_2, crystallizes in the isometric system and often occurs as good crystals. It has a conchoidal fracture, a hardness of 6-6.5, a specific gravity of 4.95-5.10, a metallic luster and a brass-yellow color. It is present in small amounts associated with the silicified tuff along the walls of the pyrophyllite bodies and in the lenses of silicified country rock included in the deposits.

Chlorite

Chlorite, probably clinochlore, has the formula $H_8Mg_5Al_2Si_3O_{18}$, crystallizes in the monoclinic system and usually occurs as flakes or scales. It has a hardness of 2-2.5, a specific gravity of 2.65-2.78, a pearly luster, and a grass-green to olive color. Chlorite occurs rather commonly in the impure portions of the pyrophyllite bodies and in the altered wall rocks.

Feldspars

Feldspars, orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$), and in one case andesine, a mixture of albite ($NaAlSi_3O_8$) and anorthite ($CaAl_2Si_2O_9$), were found in small amounts in the less silicified portions of the wall rock of the pyrophyllite bodies. Orthoclase and albite are more abundant due to the fact that they are common constituents of the rhyolitic and dacitic rocks in which the pyrophyllite was formed.

Iron Oxides

Iron oxides, chiefly hematite Fe_2O_3 and magnetite Fe_3O_4, occur in small amounts in each pyrophyllite deposit studied, but most abundantly in the footwall of the mines along Deep River north of Glendon, Moore County, where an acid iron breccia is present.

High Alumina Minerals

One or more of the high-alumina minerals andalusite (Al_2SiO_5), diaspore ($Al_2O_3H_2O$), kyanite (Al_2SiO_5) and topaz $(AlF)_2SiO_4$, are present in varying amounts in most of the pyrophyllite deposits except those in Moore County, and Conley (1962a) reported collecting a specimen from the fault zone in the Phillips mine that contained pyrophyllite, diaspore, topaz and fluorite.

The occurrence of high-alumina minerals in the pyrophyllite deposits is quite irregular, with the greatest concentrations near the footwall and lesser amounts along the hanging wall and associated with lenses of only partly altered country rock included in the deposits. Andalusite is abundant in the Hillsborough deposits. In the deposit on Bowlings Mountain, Granville County, there is considerable topaz as well as small amounts of andalusite and kyanite. Some blocks of topaz are in the pyrophyllite deposits today and represent material that was not replaced or destroyed during pyrophyllite formation.

PETROGRAPHY

A careful study of a number of thin sections cut from specimens collected at the various mines and quarries shows that the pyrophyllite deposits have been formed in volcanic tuffs and to some extent in a volcanic breccia that varied from dacitic to rhyolitic in composition.

Sections from specimens of tuff and breccia collected along the walls of the pyrophyllite bodies and from partly altered country rock included in them show that the minerals of the pyrophyllite bodies were formed in the order of quartz, pyrite, chloritoid, sericite, and pyrophyllite; and that these minerals have definite relations to each other and to the feldspars and iron oxides in the country rock.

The first change was a marked silicification of the enclosing rocks accompanied by a rapid decrease in their normal mineral content. The feldspars, rock fragments, and fine-grained groundmass of the rocks were readily replaced by quartz to the extent that the altered rocks became masses of cherty and milky quartz.

At the Womble and Phillips mines north of Glendon, Moore County and at the Staley mine 3

miles west of Staley, Randolph County, the silicification was accompanied or immediately followed by the development of pyrite, as this mineral is found in the silicified wall rocks of the mines and in included masses of silicified country rock but not in good pyrophyllite.

Chloritoid is found in varying amounts at all the prophyllite prospects and mines but is more abundant at some including the Womble and Phillips mines north of Glendon, Moore County and the Murray prospect 5 miles northeast of Hillsborough, Orange County and the Staley mine 3 miles west of Staley, Randolph County. At the Womble and Phillips mines it is apparently related to an acid iron breccia which contains considerable magnetite and hematite and forms the football of these deposits. The chloritoid at the Murray prospect and the Staley mine seems to be related to bands and zones of greenstone in the wall rocks of the bodies near the pyrophyllite.

The chloritoid was not observed replacing the iron oxides but the marked increase and close association of chloritoid with the iron oxides at every point where the latter are present suggests a close genetic relation between the two. The chloritoid was developed along with or soon after the silicification of the tuff and in thin sections is seen to have partly replaced the quartz.

Sericite is often concentrated as bands or zones along the hanging wall of the pyrophyllite bodies and to a lesser extent along the footwall. It is also present as finely divided flakes and scales and as zones through good pyrophyllite. Thin sections cut from silicified and partly prophyllitized masses from the various pyrophyllite deposits show sericite associated with pyrophyllite and having about the same relations to the quartz. The cherty or flinty masses of quartz in the pyrophyllite bodies are cracked and shattered and partly replaced by sericite.

The microscope shows pyrophyllite to be the last mineral formed. In every case silicification preceded the development of pyrophyllite.

The feldspars diminish with silicification so that feldspar and pyrophyllite are seldom found in the same section. Where pyrophyllite is found in sections with chloritoid, it occurs in every crack and opening in the sheaves and bundles of chloritoid as a replacement of the chloritoid. Practically all specimens except those from the purest pyrophyllite, contain some quartz, the amount of the latter depending upon the purity of the specimen in terms of pyrophyllite. In sections from such specimens the pyrophyllite is replacing the quartz. Sections from the masses of cherty or milky quartz associated with pyrophyllite show both sericite and pyrophyllite replacing the quartz with sericite apparently earlier than the pyrophyllite. The position of the minerals andalusite, diaspore, kyanite and topaz in the sequence is not clear, but they appear to have been formed before or early in the pyrophyllitization process as they have been replaced partially by sericite and pyrophyllite.

ORIGIN OF THE PYROPHYLLITE DEPOSITS

In considering the origin of the pyrophyllite deposits, it has been necessary to take into account their shape and distribution, their relations to the enclosing rocks, their mineralogical composition, the relations of the associated minerals to each other, and the relations of the pyrophyllite to the associated minerals and the enclosing rocks. Over the years, ideas as to the origin of pyrophyllite have changed and future development of the deposits may disclose new information that may require new explanations. This is especially true since the deposits are associated with metamorphic rocks and ideas on the origin of metamorphic rocks and their contained minerals are in a state of change.

EARLIER THEORIES

Before discussing the origin of North Carolina pyrophyllite, reference should be made to the views expressed by other writers on the origin of this mineral and the chloritoid and sericite associated with it.

Emmons (1856) considered pyrophyllite (agalmatolite) as a sedimentary rock near the base of his Taconic system. Levy and Lacroix (1888) stated that pyrophyllite occurs in metamorphic rocks while Dana (1909) classed it as a mineral formed at the base of schists or as a mineral of the crystalline schists and Paleozoic metamorphics.

Clapp (1914) described pyrophyllite deposits on the west side of Vancouver Island, British Columbia. Both alunite and pyrophyllite occur in andesite, dacite and associated pyroclastic rocks. This series and in particular its fragmental parts, has been metasomatically altered to quartz-sericite-chlorite rocks, quartz-sericite rocks,

quartz-pyrophyllite rocks and quartz-alunite rocks. Clapp concluded that most of the mineralization was caused by hot sulphuric acid solutions of volcanic origin which were active during the accumulation of the pyroclastic rocks, and as a result of relatively shallow depths and low pressures. He postulated little change in the bulk composition of the original volcanic rocks and interpreted most of the new minerals as having been developed from feldspars. In general, however, the quartz-pyrophyllite rocks show a net gain in alumina, a loss of potash and either a loss or a gain in silica.

Buddington (1916) and Vhay (1937) have described in detail the pyrophyllite deposits in the Conception Bay Region of Newfoundland. These deposits occur in a thick series of Precambrian rhyolite and basalt flows which contain interlayered breccias, tuffs and some waterlaid materials. These volcanic rocks were altered regionally with the development of abundant chlorite and silica. Locally, some of the rocks were pyrophyllitized, some pinitized and some silicified.

Some of the pyrophyllite concentrations are found in rhyolite breccias and conglomerates, but most are limited to the rhyolite flows. The pyrophyllite itself forms single, well defined veins, as well as series of inter-connecting veins, lenses and pockets. The development of the pyrophyllite evidently involved the introduction of large amounts of alumina, the replacement of alkalies by hydroxyl, and the removal of silica, both that occurring as free quartz and that in the other minerals. Much of the pyrophyllitized rock may once have been a relatively homogeneous glass.

Buddington (1916) concluded that these deposits were formed by the metasomatic replacement of previously silicified rhyolites by thermal waters under conditions involving dynamic stress and intermediate temperatures and pressures. The solutions evidently moved along fault or shear zones, and the deposits have a marked schistosity. Vhay (1937) concluded that the individual flakes of pyrophyllite have a random orientation and that the schistosity of the deposits represent an inherited feature preserved by differential replacement along schistose structures already established.

The pyrophyllite deposits in the San Dieguito area of San Diego County, California, have been described in detail by Jahns and Lance (1950). These deposits were formed by the alteration of volcanic flows, breccias and tuffs that ranged in composition from andesite to rhyolite.

Jahns and Lance (1950) described the origin of these deposits as follows: "The mode of occurrence of the San Dieguito pyrophyllite, particularly its distribution with respect to fractures and shear zones in the host volcanic rocks, indicates that it was formed by replacement of these rocks. Its development was accompanied by introduction of SiO_2, Al_2O_3 and probably OH. The phyrophyllite bearing rocks, including those of highest grade, contain fresh pyrite and other sulfide minerals at depths in excess of 20 feet in most parts of the area. Both pyrophyllite and sulfides appear to be hypogene, and are plainly earlier than the widespread iron oxides, manganese oxides and clay minerals of supergene origin.

"Under the microscope both pyrophyllite and quartz replace feldspars and other original minerals of the volcanic rocks, and in many places the two replacing minerals are of the same general age. As pointed out by Bastin and others, (1931) aggregate, rather than sequential replacement, is characteristic of hypogene processes. Zonal distribution of replacing minerals with respect to remnants of earlier minerals, a feature so common in supergene replacement, is conspiciously absent from the pyrophyllite-bearing rocks. Moreover, the replacement is not particularly selective; the pyrophyllite, although first attacking parts of the groundmass in the volcanic rocks is generally distributed throughout the phenocrysts and groundmass minerals."

They conclude: "The metamorphism of the volcanic rocks in the San Dieguito area, and the subsequent introduction of silica and pyrophyllite almost certainly took place during late Triassic or Cretaceous time. A considerable thickness of volcanic rocks was removed by erosion prior to deposition of the latest Cretaceous sediments in the region, so that it is impossible to establish a maximum depth at which the pyrophyllite deposits were formed. At no place is the total thickness of the Santiago Peak volcanics known, but it may well have amounted to several thousand feet. On the basis of the general geologic relations and the indirect evidence from laboratory investigations, it seems likely that the San Dieguito pyrophyllite deposits were formed hydrothermally under conditions of intermediate temperatures

and pressures. This is in accord with conclusions reached by Buddington (1916) for somewhat similar deposits in the Conception Bay region of Newfoundland, and by Stuckey (1925) for the deposits in the Deep River region of North Carolina. In contrast, the deposits on Vancouver Island, British Columbia, appear to have been formed under near surface conditions."

Based on a study of samples collected from various pyrophyllite deposits of North Carolina, Zen (1961) tended to disregard the effect of hydrothermal replacement solutions on the formation of the pyrophyllite bodies. He considered the presence of the three phase mineral assemblage of the ternary system Al_2O_3 — H_2O —SiO_2 to indicate that water acted as a fixed component. He further noted, however, that to say water acted as a fixed component did not completely imply the absence of a free solution phase (hydrothermal solutions). Such a phase could have existed, but certainly did not circulate freely through the system destroying the buffering mineral assemblages.

Conley (1962a) concluded: "The bulk chemical composition of the pyrophyllite deposits is essentially the same as that of the country rock. All of the chemical elements present in the pyrophyllite deposits are present in the country rock, with the exception of fluorine, copper and gold. These elements are associated with quartz veins and silicified zones and were obviously brought in from an outside source. The pyrophyllite deposits could have formed in place with either addition or substraction of chemical elements if the elements were properly segregated and recrystallized into new minerals."

LeChatelier (1887) determined the temperature at which pyrophyllite loses its water and found two points of marked loss, one at 700° and the other at 850° C. Stuckey (1924) made a comparative dehydration test of pyrophyllite and sericite and found that sericite lost its water much faster than pyrophyllite at lower temperatures and at 750° C was practically dehydrated while the pyrophyllite held about 1 percent of its water which was finally lost at approximately 900° C.

Rogers (1916) classed sericite as a typically low temperature mineral associated with the last stages of hydrothermal alteration while Lindgren (1919) classed it as a mineral common to hydrothermal alterations at shallow and intermediate depths and pointed out that in acid rocks of the rhyolitic type silicification and sericitization are common near the surface, but did not agree with Rogers that sericite is a late mineral.

While much has been published regarding the nature of chloritoid there is little definite information on its genesis. Clark (1920) stated that chloritoid is formed in schists where much iron and water are present, and that it is intermediate between the micas and chlorite and may alter into either. Manasse (1910) described a schist of sericite, quartz, rutile, tourmaline, chlorite and epidote from the Alps of Italy, closely associated with and occurring on both sides of a marble, in which chloritoid is abundant.

Niggli (1912) in a study of the chloritoid and ottrelite groups of the Swiss Alps decided that the two minerals are identical. He pointed out that chloritoid is abundantly developed in schists that were originally high in clay content and thought that its formation was directly due to pressure and relatively independent of temperature. He gave a diagram showing that regardless of temperature, chloritoid is formed with an increase in pressure and conversely it drops out when the pressure diminishes.

ANALYSES OF ROCKS

In Table 1, on page 17, there are a number of chemical analyses of rocks and minerals from the Carolina Slate Belt of North Carolina and for comparison, several analyses of similar rocks from other regions. Number 1 is a rhyolite from Flat Swamp Mountain in the Carolina Slate Belt of Davidson County, North Carolina, while Number 2 is a devitrified rhyolite from South Mountain, Pennsylvania. Number 3 is an average of 115 analyses of rhyodacite and rhyodacite-obsidian obtained from widespread areas. Number 4 is dacite from Kemp Mountain in the Carolina Slate Belt of Davidson County, North Carolina. Number 5, is dacite tuff, 1 mile southeast of Monteith Bay, Vancouver Island, while Number 6, is the same type of rock a short distance away that has been silicified and altered to a cherty quartz-sericite rock. Numbers 7, 8, 9 and 10, represent commercial pyrophyllite from 4 mines in North Carolina.

Analyses Number 1 through 5, Table 1, page 17, represent normal or average rhyolite and dacite rock types, and as is to be expected the bulk composition of these analyses is remarkably uniform. SiO_2 varies from 66.27 to 74.67 percent, Al_2O_3

from 10.78 to 15.39 percent, CaO from 0.34 to 3.68 percent, Na_2O from 3.40 to 5.46 percent, K_2O from 1.74 to 3.01 percent, and H_2O from a trace to 0.68 percent. Analyses number 7 through 10, represent average commercial pyrophyllite, and as might be expected the bulk composition of these analyses is remarkably uniform. SiO_2 varies from 57.58 to 64.68 percent, Al_2O_3 from 28.34 to 33.31 percent, CaO from a trace to 0.72 percent, Na_2O from 0.06 to 0.38 percent, K_2O from a trace to 3.90 percent, and H_2O from 5.40 to 5.86 percent.

This change in bulk composition from rhyolite and dacite to pyrophyllite was brought about by silicification of the rhyolite and dacite to a cherty quartz rock as shown in analysis number 6, followed by replacement to pyrophyllite. As silicification advanced there was a decrease in alumina and alkalies and an increase in silica. Replacement by pyrophyllite, in some cases, preceded or accompanied by sericite, resulted in a decrease in silica and an increase in alumina, potash increasing with the sericite content, while water increased from about 1 percent to an average of 5.59 percent.

The conditions indicated by the above analyses may be observed at many of the pyrophyllite deposits in the area. Beginning in walls of unaltered rhyolitic or dacitic tuff there is a gradual transition through silicification, sericitization and pyrophyllitization to lenses and masses of practically pure pyrophyllite in the interior of the bodies. As a result, the mineral bodies contain walls of silicified country rock that on the interior portions have been more or less sericitized and partially to completely pyrophyllitized.

Table 1. Analysis of Rhyolite, Dacite and Pyrophyllite

	1	2	3	4	5	6	7	8	9	10
SiO_2	74.67	73.62	66.27	72.33	73.22	87.80	64.53	57.58	64.68	64.54
Al_2O_3	10.78	12.22	15.39	14.56	13.46	9.08	29.40	33.31	28.34	28.88
Fe_2O_3	1.25	2.08	2.14	0.15	2.33	0.40		0.33	0.60	0.45
FeO	2.11		2.23	2.22	0.96	nd	0.67	nd	nd	nd
MgO	trace	0.26	1.57	0.91	0.42		trace	trace	trace	trace
CaO	1.47	0.34	3.68	2.55	1.50		trace	trace	0.72	0.36
Na_2O	5.31	3.57	4.13	3.40	5.46	0.62	0.28	0.06	0.38	0.12
K_2O	2.68	2.57	3.01	2.82	1.74	1.70	trace	3.90	0.01	0.18
H_2O	0.59		0.68	0.30	0.62	1.04	5.86	5.56	5.54	5.40
CO_2	1.30									
Ignition		0.40								
Total	100.16	99.09	99.26	99.24	99.71	100.04	100.33	100.74	100.27	99.33

1. Rhyolite from Flat Swamp Mountain, North Carolina, Pogue (1910) p. 54
2. Devitrified rhyolite from South Mountain, Pennsylvania, Williams (1892) p. 494
3. Average of 115 analyses of rhyodacite and rhyodacite-obsidian, Nockolds (1954) p. 1014
4. Dacite from Kemp Mountain, Davidson County, North Carolina, Pogue (1910) p. 57
5. Dacite tuff 1 mile southeast of Monteith Bay, Clapp (1914) p. 120
6. Silicified dacite tuff (cherty quartz-sericite rock) Monteith Claim, Clapp (1914) p. 120
7. Pyrophyllite from Rogers Creek Mining Company's mine, Pratt (1900), p. 26
8. Pyrophyllite from Standard Mineral Company's mine, Stuckey (1928), p. 36
9. Pyrophyllite from Womble mine, Stuckey (1928) p. 36
10. Pyrophyllite from Gerhard Bros., Staley, North Carolina, Stuckey (1928) p. 36

ORIGIN OF NORTH CAROLINA PYROPHYLLITE

The field, microscopic and chemical evidence indicates that the pyrophyllite deposits in North Carolina have been formed through the metasomatic replacement of acid tuffs and breccias of both rhyolitic and dacitic composition. The development of pyrophyllite was accompanied by the introduction of SiO_2, Al_2O_3 and water. The quartz, pyrite, chloritoid, sericite and pyrophyllite in the mineralized bodies are apparently of hypogene origin.

Evidences that the deposits have been formed by replacement are as follows:

(1) Gradational contacts between pure pyrophyllite and the unaltered country rocks.
(2) The preservation of structures of the primary rocks in the mineralized rocks, such as bedding planes of the finer tuffs, and fragmental outlines of the coarser tuffs and breccias.
(3) The presence of masses and lenses of practically pure or only partly altered country rock, apparently unattached and completely surrounded in the mineral bodies.
(4) The introduction of some elements and the removal of others.
(5) The lack of any noticeable change in the volume of the original rocks during the mineralization processes.
(6) The massive and homogeneous structure of the pyrophyllite.

The following sequence of events is deduced:

(1) The metamorphism of the volcanic fragmental and flow rocks in which the mineral bodies were later formed.
(2) The silicification of the volcanic fragmental and flow rocks by metasomatic processes as is indicated by the presence of original structures of the volcanics in the silicified materials, and by the presence of entirely surrounded fragments of only partly silicified volcanic rocks in the quartz areas.
(3) The development of pyrite in the silicified areas, accompanying or immediately following the silcification of the volcanics.
(4) The development of chloritoid to some extent in all the pyrophyllite bodies and in abundance in parts of these deposits that are near iron rich formations.
(5) The development of sericite by the replacement of the previously silicified volcanic fragmental and flow rocks.
(6) The development of pyrophyllite by replacement of the previously silicified and mineralized tuffs and breccias, closely associated with or immediately following the formation of the sericite.

SOURCE OF MINERALIZING SOLUTIONS

The pyrophyllite forming solutions were evidently of hypogene origin, but their source is not so easily demonstrated. The only intrusive igneous rocks that are exposed near any pyrophyllite deposits in the area are diabase dikes, which are clearly later than the pyrophyllite mineralization. While none of them are known to be exposed in or near a pyrophyllite deposit there are a great many granite type intrusive rocks exposed at widely scattered localities in the pyrophyllite area.

During the latter half of the nineteenth century there were a number of active gold and copper mines throughout the Carolina Slate Belt that were important enough to receive considerable attention in reports of the North Carolina Geological Survey between 1856 and 1917. Nitze and Hanna (1896) pointed out that the gold and copper deposits throughout the Carolina Slate Belt are very similar and that much silicification had accompanied the formation of the ores. They attributed this mineralization to hot carbonated, alkaline waters of deep seated origin. Laney (1910) found much silicification associated with the ore bodies (gold and copper) at Gold Hill, and concluded that the mineralization had been produced by hot solutions given off from a granite that had been intruded into the volcanics in the immediate vicinity of the ore bodies. Pogue (1910) found practically the same conditions in the Cid district of Davidson County, except that there were no known intrusive igneous rocks to have furnished the solutions. He concluded, however, that there were large igneous masses intruded into the rocks of the district from below, but that these rocks did not reach the surface.

If Nitze and Hanna are correct in their statements that the gold and copper mines of the entire slate belt are in general alike, and if Pogue is correct in assuming a large intrusive magma below the Cid district that belonged to a period when large amounts of igneous rocks were intruded into the Piedmont Plateau and brought near the surface, it seems that the same conditions must have existed in the pyrophyllite region and that the gold ores of the various mines were formed by hot solutions from igneous magmas below. There is a close relation between the pyrophyllite deposits and the metalliferous deposits at a number of places. One that may be used as a type example is the mine of the Standard Mineral Company near Robbins, Moore County, where the pyrophyllite schist grades directly into the silicified tuff at the old Cagle gold mine. This seems to indicate that the same source that

furnished the hot solutions to deposit the gold and copper ores in the slate belt also furnished the hot solutions to produce the pyrophyllite bodies.

CONDITIONS OF PYROPHYLLITE FORMATION

Different investigators have indicated that pyrophyllite may form under conditions varying from high temperature and pressure to low temperature and pressure such as exist near the surface.

The information available on the origin of chloritoid seems to indicate that it forms at fairly high temperatures and according to Niggli (1912) is directly dependent upon fairly high pressure.

Graton (1906) classed the gold-quartz veins of the Southern appalachians as high temperature in origin, while Laney (1910) and Pogue (1910) both indicated that the gold and copper ores of the Gold Hill and Cid districts were formed under conditions of temperature and pressure varying from high to intermediate. That the pyrophyllite bodies were formed by hot solutions given off from the same source and acting at about the same time is indicated by the close association of the pyrophyllite bodies with the old gold mines, especially the Cagle gold mine near Robbins, Moore County and at the Brewer gold mine (Powers, 1893) in South Carolina. Hafer (1913) noted the presence of copper bearing pyrite in the mine of the Southern Talc Company at Glendon, Moore County.

It is possible that at the pyrophyllite deposits there was a gradual change from high temperature and pressure to low temperature and pressure of hydrothermal alteration near the surface during the period of activity of the hot solutions. The writer, however, agrees with Buddington (1916) and Jahns and Lance (1950) and believes that the pyrophyllite deposits of the Carolina Slate Belt in North Carolina were formed under conditions of intermediate temperature and pressure.

While considering the source of the solutions and the conditions under which the pyrophyllite was formed the problem of a line of entrance for rising solutions should not be overlooked.

As has been stated above, the pyrophyllite deposits occur as elongate bodies or lenses several times as long as they are wide. In at least four localities, near Robbins, Moore County, along Deep River north of Glendon in Moore County, near Hillsborough in Orange County, and north of Stem in Granville County, the pyrophyllite bodies occur as a long zone of lenses from 50 feet to 500 feet wide and from 250 feet to 2000 feet long that can be traced for considerable distances along strike. The mineral bodies are all found in acid tuffaceous rocks and in some cases, particularly along Deep River north of Glendon in Moore County, on the limbs of anticlines (as they were worked out and mapped in the field).

It seems unreasonable for a special type of volcanic tuff to have been formed as long narrow bands so widely separated while at all other points there were such wide variations in the material. The conclusion, therefore, is that there was either faulting or some lines of weakness developed along which the solutions entered to form the mineral deposits.

Recently, Conley (1962 a) has shown that the pyrophyllite deposits along Deep River, north of Glendon, and those southwest of Robbins in Moore County, were formed along fault zones. There has not been enough detailed mapping carried out to determine the true conditions at the other deposits in the slate belt. Stuckey (1928) pointed out that the pyrophyllite bodies were formed by the replacement of acid tuffs and breccias of both dacitic and rhyolitic composition and that the tuffs and breccias remained in a state of open texture and tended to mash and shear instead of folding. It is logical to assume, therefore, that all the pyrophyllite bodies were formed along lines of weakness, either fault zones or shear zones.

RESERVES

Sufficient evidence is not available to determine accurately the reserves of pyrophyllite in North Carolina, but there is sufficient information to establish the presence of fairly dependable indicated reserves. Of some 15 known occurrences of pyrophyllite in North Carolina only 5 or 6 have been developed enough to indicate important reserves of mineable pyrophyllite. These major deposits occur near Robbins and Glendon, Moore County, near Snow Camp, Alamance County, near Hillsborough, Orange County and near Stem, Granville County. All of these deposits, with two exceptions occur along prominent hills or ridges. The Glendon deposits occur in gently undulating topography, while that near Robbins occurs in a relatively flat area covered largely by a thin veneer of Coastal Plain sand.

To-date, with one exception, all the pyrophyllite mining in the State has been carried out largely from shallow pits and open cuts that have seldom reached a depth greater than 50 or 75 feet. The one exception to these conditions is at the mine of the Standard Mineral Company at Robbins, Moore County, where a shaft 650 feet deep and drifts and stopes are being used. In none of these pits, open cuts, or mines has there been any major change in the pyrophyllite or associated minerals with depth.

Even though pyrophyllite should not be found in commercial amounts to depths of over 200 feet, there is enough available to that depth, in the more promising deposits, to support an important industry for many years under efficient mining, milling and concentration practices.

The processes of milling have been such that everything that went into the mill had to be pure enough to make a good finished product. It is only recently that any attempt has been made to use separating and concentrating machinery in the removal of grit and other impurities. This has meant that a large amount of material which contained 50 percent or more of pyrophyllite has been going on the dumps as waste. If the methods of milling could be improved to the point where all material containing as much as 40 to 50 percent pyrophyllite could be utilized, it would practically double the available amount on the basis of milling practices formerly carried out.

Pratt (1900) pointed out that the pyrophyllite is continuous and of considerable, though unknown depth. Hafer (1913) suggested that pyrophyllite should be found to the same depths that the gold mines of the area have reached, and indicated that gold had been mined to a depth of 500 feet. This statement seems very reasonable when it is realized that there is a close relation in the distribution of the gold and pyrophyllite mines, and also a strong possibility that the solutions forming both come from the same source.

Stuckey (1928) stated: "Taking into consideration the mineralogy and origin of the deposits, the source of the solutions and the relations in the distribution of the gold and pyrophyllite deposits, it seems reasonable to expect pyrophyllite in commercial amounts to a minimum depth of 500 feet. This statement does not mean that every pyrophyllite deposit can be developed into a mine at that depth. It does mean, however, that all indications point to a depth of that magnitude for the larger bodies which really show promise at the surface."

The results obtained in exploring for pyrophyllite over the intervening years have borne out this statement. Some small prospects have been explored that did not prove continuous with depth, but drill holes more than 500 feet deep have failed to reach the limits of the major deposits.

The pyrophyllite deposits occur as irregular lenses 50 to 500 feet wide and 500 to 1500 or more feet long. The bodies of workable pyrophyllite usually occur near the center of the deposits and vary in width from a few feet to more than 100 feet. Pyrophyllite has a specific gravity of 2.8 to 2.9 and weighs 175 pounds per cubic foot. Each 100 feet of length and depth of a pyrophyllite body 100 feet wide should yield 50,000 tons allowing for a 60 percent recovery. Using these figures and assuming recovery to a depth of 400 to 500 feet, a reserve of some 10 to 12 million tons of pyrophyllite is indicated in North Carolina.

During the past 15 years it has been frequently stated that all the really promising pyrophyllite deposits in North Carolina had been discovered and were controlled by three or four major mining companies. Recently, detailed prospecting by two major companies has resulted in the discovery of promising occurrences of pyrophyllite in three new areas. These deposits have not been explored and detailed information on them is not available. These discoveries are interesting, however, as indicating that undiscovered bodies of pyrophyllite are still available in North Carolina to those willing to do the necessary prospecting to find them.

MINING METHODS

The first reference to pyrophyllite mining in North Carolina was by Emmons (1856, p. 217) who stated: "Large quantities have been ground the last year in Chatham County for the New York market." He, also stated (p. 53) "The rock does not split readily with gunpowder; when quarried in this mode, as at Hancock's, it breaks out in illshapen shattered masses. Hence it should be cut out with a sharp pick or an edged instrument of suitable form."

At first prospecting and mining were carried out by pits, shallow shafts, drifts and open cuts. As demands for larger quantities increased and off color material became salable, open cuts—

made possible by information from diamond drilling and by modern earth-moving machinery have furnished most of the production. The largest, and only modern underground pyrophyllite mine in North Carolina, is operated near Robbins, Moore County, through a 650 foot shaft, drifts and stopes.

PROCESSING

The processing of pyrophyllite has changed slowly through the years as demands and uses for the mineral have increased and changed. Prior to about 1855 it was used only locally—for stove linings, fireplaces, chimneys, mantels and gravestones—and was cut and shaped to fit the particular need. The production of pyrophyllite crayons was started about 1880 and continued until about 1920. Ground pyrophyllite was first produced in 1855, (Emmons 1856, p. 217). From 1855 to 1913 grinding was carried out, first at Hancock's Mill and later at Glenn's Mill, both located on Deep River near the present village of Glendon, Moore County. The grinding stock was carefully selected, air dried, and crushed. It was then crushed by hand, ground with millstones and passed through bolting cloth.

In 1902 the first mill constructed exclusively for grinding pyrophyllite was built near a deposit along Deep River, north of Glendon. This was followed in 1904 by a second mill on another deposit about a mile away. Both mills were alike in that the grinding stock was air dried and crushed. In one mill the crushed material was passed through a hammer mill, ground with millstones, fed into a ball mill, ground 8 hours and screened. In the other mill, the crushed material was ground with millstones, the fines removed by air, and the coarse material fed into a ball mill, ground, and screened. Both of these mills were abandoned by the end of 1921.

Before 1918, all the known pyrophyllite deposits of any importance were located along the north side of Deep River, in the general vicinity of Glendon, Moore County. In that year, what later proved to be the largest known pyrophyllite deposit in the state was discovered about 2 miles southwest of Robbins, Moore County, when wagon wheels brought up a fine white material that proved to be pyrophyllite. The first modern grinding plant was built on this property about 1921. The process first used consisted of crushing, grinding in a hammer mill and screening. The hammer mill did not prove satisfactory for grinding, and after some modifications, the process was abandoned. A new process was installed, consisting of crushing and grinding in a roller mill, and screening. As the ceramic market for pyrophyllite has become more important, conical pebble mills for fine grinding have been installed in this and other plants in the State.

At the present time three companies—the Standard Mineral Company at Robbins, the General Minerals Company at Glendon, and the Piedmont Mineral Company at Hillsborough are mining and processing pyrophyllite for market. A fourth company, the North State Pyrophyllite Company at Greensboro is mining pyrophyllite and producing a variety of pyrophyllite refractories but is not selling pyrophyllite as such. None of these companies is carrying out beneficiation or true mineral dressing on crude pyrophyllite. By selective mining, blending, grinding and screening, a wide variety of grades, standardized both as to grain size and chemical composition, is being produced for fillers and specialty products and for use in ceramic bodies and refractories.

In the processes used to-date, only pyrophyllite pure enough to make a salable finished product has been used. As a result, much good material containing 40 to 60 percent pyrophyllite has been discarded. In view of the somewhat limited reserves and increasing demands, too much good material is being left in the ground or thrown on the dumps. However, as demands have increased, improved methods of grinding and screening have reclaimed much material formerly discarded. Research on the removal of iron, free silica and other impurities has been carried out. As a result, larger tonnages of pyrophyllite of higher quality than that now being produced should be made available to industry as demands increase.

USES OF PYROPHYLLITE

Pyrophyllite has a wide range of uses which are dependent largely upon the remarkable physical properties of the mineral. Most of these uses are similar to those of talc, to the extent that the two minerals are often used interchangeably. Pyrophyllite is a hydrous aluminum silicate with the formula $H_2Al_2Si_4O_{12}$. It occurs in several common habits, the best known, perhaps, being the rosette-like aggregates of radially disposed fibers and elongate flattened crystals. A flaky or foliated

variety with a slaty cleavage is common along the north side of Deep River and near Robbins in Moore County. A third variety consists of masses of grains and fibers that lack orientation or layering. In some of the finer-grained occurrences, the pyrophyllite individuals are rosette-like in detail although this is rarely apparent to the unaided eye.

While the chemical formula of theoretically pure pyrophyllite is rather simple, most commercial pyrophyllite contains varying small quantities of the elements, iron, calcium, magnesium, sodium, potash and titanium. The chemical composition can be useful in predicting the behavior of pyrophyllite where very exact controls are required in the manufacture of certain products. In ceramic bodies, for example, such properties as color, shrinkage and absorption of tile bodies can be predicted in terms of the raw pyrophyllite used in them.

The nature and uses of several types of pyrophyllite from North Carolina have been effectively summarized in a booklet published by the R. T. Vanderbilt Company (1943) of New York. For further details on the properties of pyrophyllite the reader should consult Grunner (1934), Hendricks (1938), and Ross and Hendricks (1945).

Prior to about 1855, pyrophyllite was used locally for tombstones, and such stones, still well preserved, may be seen in two or more cemeteries near Glendon. Emmons (1856) described it as an excellent substitute for soapstone in stove linings, fireplaces, chimneys and mantles. He stated that it was not suitable for paint as it became translucent when mixed with oil, but described it as a filler that helped retain the perfume in soap and added that large quantities were ground for the New York market in 1855. He described it as suitable for anti-friction powder and use in cosmetics and quoted Dr. Jackson to the effect that it would make a very refractory material for stoneware and crucibles.

At present, pyrophyllite is used chiefly in the manufacture of insecticides, rubber, paint, ceramics, refractories, plastics, and roofing paper. It has a number of minor uses for products including cosmetics, wallboard, rope and string, special plaster, textile products, paper, linoleum and oilcloth, and several types of soap. The best production figures available indicate that about one half of the current annual production goes into insecticides, rubber and paint, one third into ceramics and refractories and the remainder into plastic, roofing paper, linoleum, cosmetics and a host of minor uses.

According to Jahns and Lance (1950): "A large part of the domestic production of pyrophyllite is incorporated into paints and particularly non-reflecting and other special types in which flake pigments of light color are desired. High oil absorption of ground pyrophyllite and its freedom from grit also are desirable properties for paint use. Ground material is employed as a filler in rubber goods, certain roofing and flooring materials, special plasters, plastics, insecticides, textile products, paper, linoleum and oilcloth, rope and string, several types of soap and in some fertilizers. It serves as a "loader" in paper and textile fabrics, where its whiteness and resistance to the effects of fire and weather are particularly desirable. This resistance also partly accounts for its use in roofing papers and other asbestos and asphalt goods. Its corrosion resistance makes it an especially satisfactory filler in battery cases. There are indications that it also may serve effectively as a low noise filler in phonograph records.

"With a low bulk density and slight acidity in ground form, high absorptive characteristics, and superior qualities as a flake-form dusting agent, pyrophyllite is an excellent carrier for such active insecticides as DDT, nicotine, pyrethrum and rotenone. The flakiness of the mineral leads to desirable adhesion on leaves and other parts of dusted plants, and its softness and freedom from grittiness when finely ground make for reduction of wear on nozzles and other parts of mechanical insecticide dispensers.

"Pyrophyllite of great purity and whiteness has been used as a base for cosmetics and toilet preparations, but the total amount is not large. The lubricating properties of the mineral underlie its use in some greases, in tires and other rubber goods, on machine-driven box nails, and in various kinds of dies. On the other hand, it also is employed as a fine, "soft" abrasive in the scouring and polishing of certain foodstuffs, as well as some painted or lacquered surfaces. It serves as a high-quality packing and insulating material, as a constituent of adhesive, corrosion-resistant covering compounds, and as an absorbent for oil substances in a wide variety of products. It, also, can be processed for use in crayons and pencils.

"As a constituent of ceramic bodies, pyrophyllite is being more and more widely used. It is a good substitute for feldspar and quartz in wall-tile bodies, as it decreases their shrinkage and their crazing by thermal shock or moisture expansion. It also is employed as a source of aluminum in enamels, and as a raw material for semivitreous dinnerware and some types of refractories."

Uniformity of grain size and mineral content is becoming important for all uses. For ceramics, whiteware, and wall tile, where the size of the finished product must be controlled accurately, pyrophyllite is one of the best materials available provided it is perfectly uniform in grain size and composition. For use in special refractories, such as car tops for tunnel kilns, monolithic furnace lining and furnace lining requiring rapid temperature changes, pyrophyllite makes an excellent body that is shock-resistant.

MINES AND PROSPECTS

Beginning on the northeast in Granville County, near the Virginia line, and continuing in a southwesterly direction to the southwestern part of Montgomery County is an irregular zone, along the eastern part of the Carolina Slate Belt, that contains all the known occurrences of pyrophyllite in North Carolina. Prospects, outcrops and/or mines are known to occur in Granville, Orange, Alamance, Chatham, Randolph, Moore and Montgomery counties.

GRANVILLE COUNTY

Daniels Mountain

Pyrophyllite bodies occur in three localities in Granville County. One of these is on Daniels Mountain, a prominent ridge that rises nearly 200 feet above the surrounding countryside. Daniels Mountain is located approximately 9 miles slightly northwest of Oxford, about 1.5 miles east of North Carolina Highway 96 and just south of Mountain Creek. The area is underlain with acid volcanic rocks. Small amounts of pyrophyllite occur on the north end of this ridge. No prospecting had been done at the time the writer visited the ridge. Espenshade and Potter (1960) described Daniels Mountain as follows: "Another deposit of pyrophyllite occurs on a prominent ridge rising nearly 200 feet above the surrounding countryside, about 14 miles northeast of Bowlings Mountain deposit, 9 miles northwest of Oxford, and about 1½ miles east of North Carolina Highway 96. Float and low outcrops of dense siliceous rock are abundant for about three-quarters of a mile along the ridge. Chloritoid occurs in some rock, disseminated hematite and magnetite are also present. Blocks of massive pyrophyllite, 1 to 2 feet long, are distributed along a distance of 600 to 700 feet at the north end of the ridge. Other aluminous minerals have not been discovered."

Bowlings Mountain

A major pyrophyllite deposit is present on Bowlings Mountain, a prominent hill that is located about 3 miles northwest of Stem and 10 miles southwest of Oxford, Granville County. The hill rises to an elevation of about 700 feet above sea level (approximately 200 feet above the surrounding countryside), has a trend of about N 15° E and conforms to the pattern of a series of rather pronounced ridges to the northwest. The pyrophyllite deposit which lies along the crest and northeastern slope of the mountain is approximately 500 feet wide and more than 1500 feet long. The strike is N 15° E and the apparent dip is 70° to 80° to the northwest, paralleling the strike and dip of the country rock.

Prospecting was first carried out on the southwest end of the ridge and near the western slope, about the turn of the century, when a pit known as the Harris prospect was opened. This pit which was 15 to 20 feet long, 6 feet wide and 6 to 10 feet deep was opened on an outcrop of radiating or needle-like crystals of iron-stained pyrophyllite. About 1940 a shaft was sunk to a depth of approximately 80 feet near these old pits. The phyrophyllite found in this shaft did not differ materially from that found in the surface pits and the work was abandoned.

About 1949 or 1950, Carolina Pyrophyllite Company began exploration and development work here, consisting of pitting and trenching followed by drilling, during the course of which a large tonnage of pyrophyllite was discovered. Following this exploration work, 2 opencuts were developed from which considerable pyrophyllite was mined and shipped by truck to a grinding plant at Staley, some 80 miles to the southwest, before that mill was closed in 1960.

On the southeast or footwall side of the deposit is a medium-grained, dense, quartzitic rock containing pyrite that seems to represent the footwall of the deposit. Northwestward from the quartzitic rock mineralization is quite apparent. Massive and crystalline pyrophyllite occurs in very fine-grained schistose zones in sericite schist. Tough, white, granular rock containing coarse-grained andalusite, quartz, and pyrophyllite is present in parts of the deposit. Massive topaz identical in appearance with the dense topaz from the Brewer mine in South Carolina is abundant as float adjacent to the quartzitic footwall. Here, it is found concentrated in a series of rather poorly defined zones covering an area more than 100 feet long and 200 feet wide. Individual pieces range from less than one-fourth inch to 3 feet in diameter. Outcrops in the area are rare, but, in recent road cuts along the northern end of the mountain, topaz is exposed as a series of narrow, irregular veinlike masses in sericite schist. It also occurs as stringers a few inches thick in phyrophyllite in the southernmost open cut. The topaz occurs as boulders in the quartzitic rock, filling cracks and fractures, as small knotty masses disseminated throughout the rock and as large massive pieces which in some cases appear to grade into the host rock. The andalusite and topaz, older than the pyrophyllite, appear to replace the country rock and in turn are replaced by pyrophyllite.

Long Mountain

About a mile or two to the northwest of Bowlings Mountain is a zone of irregular hills from 1 to 1.5 miles wide and 4 to 5 miles long that is known as Long Mountain. This ridge trends about north 20 degrees east and lies partly to the north and partly to the south of State Road 1139. The highest point on Long Mountain is a knob north of State Road 1139 and along the western side of the ridge that is known as High Rock Mountain. It rises to an elevation of some 150 to 200 feet above the surrounding countryside and 700 feet above sea level. Pyrophyllite outcrops of varying size and promise, some of which have been prospected and some of which have not, are widely scattered throughout Long Mountain.

Robbins Prospect 1

On the Robbins property, in the vicinity of High Rock Mountain is an area about 1000 feet wide and 2000 feet long on which radiating pyrophyllite, associated with quartz veins, is common but not abundant. No prospecting has been done in this general area and the potential for commercial deposits of pyrophyllite is unknown. Most of the pyrophyllite visible is badly iron stained.

Jones Prospect

To the east of the Robbins tract and about 1500 feet north of State Road 1139, some 4 or 5 prospect trenches that varied in length from 150 to 300 feet and up to 8 or 10 feet deep were opened on the Jones land some 8 or 10 years ago. Details of this prospecting are not available but indications for pyrophyllite are good. The country rock is a medium to fine-grained felsic volcanic tuff that has a cleavage which strikes north 20 to 30 degrees east and dips steeply to the northwest. Both foliated and radiating pyrophyllite, some of which is iron stained, is farily common.

R. E. Hilton Property

Adjoining the Jones land on the east is the land of R. E. Hilton on which there is a zone varying from 250 to 500 feet wide and about 1000 feet long that contains promising outcrops of pyrophyllite. No prospecting has been done on this property but bold outcrops of good pyrophyllite make it appear promising.

E. C. Hilton Property

Along the east side of Long Mountain and south of State Road 1139 there are two interesting areas of pyrophyllite on the land of E. C. Hilton. The first of these, which is about 1500 feet south of State Road 1139 and near a recent sawmill site, consists of about three acres on which bold outcrops of pyrophyllite mixed with similar outcrops of felsic volcanic rocks are abundant. No prospecting has been done here but the outcrops indicate the possible presence of important amounts of good pyrophyllite. The other area is on a prominent hill about 1500 feet farther southeast and beyond a small stream. Surface exposures of pyrophyllite are not extensive but some interesting outcrops of radiating crystals may be seen. Considerable prospecting in the form of drilling, the results of which are not known, was carried out here about 8 or 10 years ago. The country rock at both of these prospects is a medium to fine-grained, felsic volcanic tuff.

Robbins-Uzzell Property

About 1500 feet south of State Road 1139 and to the southeast of High Rock Mountain is an unnamed ridge that ranges between 500 and 600 feet above sea level. This ridge which begins near the head of an east flowing stream continues in a south 20 degrees west direction to and beyond Dickens Creek a distance of 1.5 to 2 miles. The northeast end of this ridge is a part of the Robbins tract while the southwest end is a part of the Uzzell land. No prospecting has been done on this ridge but outcrops of excellent pyrophyllite remarkably free of iron stain make it promising as a source of pyrophyllite.

Robbins Prospect 2

Just east of Knap of Reeds Creek and a short distance south of State Road 1139 is a power transmission line tower. Beginning near this tower and extending to the southwest for a distance of 800 to 1000 feet is a pyrophyllite body that is 300 to 400 feet wide. The cleavage in this mineral body strikes about north 35 to 40 degrees east and dips steeply to the northwest. The rocks surrounding this deposit consist of medium- to fine-grained acid volcanic materials. The northwest 150 to 200 feet of the deposit consists largely of good quality pyrophyllite that varies from massive to foliated. The southeast or footwall portion to a width of 75 or 100 feet appears to be in part sericite. This is a promising deposit that could contain considerable high-grade pyrophyllite.

ORANGE COUNTY

Murray Prospect

Pyrophyllite deposits occur in three localities in Orange County. One of these known as the Murray property is located on a ridge about 5 miles northeast of Hillsborough near the intersection of State Roads 1538 and 1548. State Road 1538 passes just to the north of the property while State Road 1548 lies just to the east. Here along a ridge in an area of medium to fine-grained acid volcanic rocks are old prospect pits up to 30 feet long by 10 feet wide and 6 feet deep. Most of the pits are about 10 feet long by 4 feet wide and 6 feet deep. The pits are scattered over an area 75 to 100 feet wide and 500 feet long. Pyrophyllite of the foliated or schistose variety is present on the dumps and in the sides of the pits as well as in an occasional outcrop. Chloritoid is abundant in the walls of some of the pits, especially near narrow bands of greenstone in the felsic volcanics. This area probably contains pyrophyllite of value.

Hillsborough Mine

Immediately south of Hillsborough are three prominent hills which trend northeast and parallel the major geologic structure of the area. From northeast to southwest these hills are often designated Hill No. 1, Hill No. 2 and Hill No. 3. Although the three hills appear to be much alike in many ways, the developed mineralization is limited to Hill No. 1, the northeastern most of the three. Here, prospecting was started in 1952 by the North State Pyrophyllite Company followed by mining a few years later. The zone of mineralization as exposed by the open cut mining operations is some 1500 feet long and from 100 to 250 feet wide. It strikes approximately N. 50° E. and dips from 60 to 80 degrees to the northwest. The mineral body has a footwall of dense siliceous rock that forms the crest of the hill or ridge and a hanging wall of sericite schist. The chief minerals in the deposit in the order of decreasing abundance are silica, massive and crystalline or radiating pyrophyllite, sericite, andalusite and topaz. Minor amounts of diaspore have been reported. Andalusite is abundantly disseminated throughout the deposit and seems to be considerably more abundant than pyrophyllite in much of the deposit. It is light blue, greenish blue or gray in color, has a pronounced blocky appearance, and occurs as small fragments about one-fourth inch in diameter, disseminated sparingly to abundant throughout the quartzose rock. Topaz occurs sparingly in the deposit, apparently being limited largely to disseminated grains and masses in the fractured quartzose footwall rock.

Recent field work indicates that to the southwest mineralization similar to that on Hill No. 1, now being worked by Piedmont Minerals Company, may be present in workable amounts on the northwest side of Hill No. 2 and in a prominent knob on the northwest side and near the northeast end of Hill No. 3.

Teer Prospects

In the southwestern part of Orange County, approximately 10 miles southwest of Hillsbor-

A. Mill

B. Open Pit Mine

Plate 2. Piedmont Minerals Company

ough, and in the general vicinity of Teer, there are a number of pyrophyllite outcrops, at least three of which have been prospected. On the north end of Mitchell Mountain and about one-half mile southwest of Teer, North State Pyrophyllite Company carried out prospecting and produced a small amount of pyrophyllite. A pit 100 feet long, 30 feet wide at the top and 15 feet deep was excavated. The strike of the cleavage is N. 55° E. and the dip is 75 degrees to the northwest. The amount of good grade pyrophyllite was too low for economic mining and the prospect was bandoned. About 3 miles almost due north of Teer and between State Road 1117 and Cane Creek, on the farm of Salina Sykes is a small prospect pit that contains minor amounts of radiating pyrophyllite. No production was made and the pit is now abandoned.

About one mile almost due north of Teer and between State Roads 1115 and 1116, considerable prospecting and some mining for pyrophyllite was carried out on the land of Clarence Bradshaw by the Carolina Pyrophyllite Company, between 1958 and 1961. A pit 200 feet long by 100 feet wide at the top and about 80 feet deep was excavated. The pyrophyllite content of the rock was originally 24 percent. The cleavage of the rock strikes about N. 55° E. and dips 75 degrees to the northwest.

ALAMANCE COUNTY

Snow Camp Mine

The Snow Camp pyrophyllite deposit being worked by the North State Pyrophyllite Company, is located on Pine Mountain about 3.5 miles southeast of Snow Camp. Prospecting was started in 1935 and over the intervening years the deposit has been a major producer of massive pyrophyllite. The pyrophyllite is shipped by truck to the company's plant at Pomona, North Carolina where it is used in the manufacture of firebrick, brick-kiln furniture and other refractory products. The deposit is a lenticular body of massive pyrophyllite and fine-grained quartz about 35 feet long and 250 feet wide. Open pit mining had developed walls nearly 100 feet high in the east and south sides of the pit until parts of them were removed for safety reasons in 1965. A rib of high-silica rock is present near the center of the deposit. This rib has been quite heavily mineralized in places and parts of it have been mined out. Coarse-grained andalusite was reported to have been found in a zone several feet wide in the northern part of the deposit, but it did not seem to be very abundant. This deposit still appears to contain a large reserve of high-grade pyrophyllite.

Major Hill Prospects

About 2 miles east of Snow Camp there are several pyrophyllite outcrops on a prominent hill, known locally as Major Hill. Major Hill lies south of State Road 1005, between State Roads 2356 and 2351, and north of State Road 2348. This hill is somewhat irregular in shape, but slightly elongate in a direction a little north of east. Two small exposures of pyrophyllite are to be seen in old prospect pits near the west end of the hill, but they do not appear to be of commercial size. Beginning about midway of the hill from west to east and along the southern slope some 250 feet from the crest is a zone of pyrophyllite about 1000 feet long and 50 to 100 feet wide that appears from outcrops to contain a considerable tonnage of high-grade massive pyrophyllite. Due to wooded conditions and lack of outcrops the geological setting could not be satisfactorily determined. It appears, however, that the pyrophyllite is in an area of medium- to fine-grained tuffaceous rocks of volcanic origin and acid composition. This deposit is on land belonging to the North Carolina National Guard.

Immediately to the east of the deposit on the National Guard land is a deposit 100 to 150 feet wide and 350 to 500 feet long on lands of the Holliday estate. This deposit contains both pyrophyllite and sericite which have a cleavage that strikes N. 50° to 60° E. and dips steeply to the northwest. This deposit appears to contain a considerable tonnage of minable material.

To the northeast of this deposit and near the east end of Major Hill is another deposit of promise on the Holliday estate. The outcrop is irregular in shape but appears to be 150 to 300 feet wide and 400 to 500 feet long. Pyrophyllite and sericite, both of which have a cleavage that strikes N. 50° to 60° E. and dips steeply to the northwest, are present in varying amounts in this deposit.

To the south and southeast of the above described deposits is another deposit on the southeast tip of Major Hill and on lands of the Holliday estate. This deposit is 150 to 250 feet wide and

400 to 500 feet long. It contains both pyrophyllite and sericite which have a cleavage that strikes N. 50° to 60° E. and dips steeply to the northwest.

Because the above described three deposits on the Holliday estate are all in wooded areas and rock outcrops are not too abundant it was not possible to establish completely the geological setting. It appears, however, that all three are in areas of medium- to fine-grained tuffaceous rocks of volcanic origin and acid composition. In the spring and summer of 1966 these deposits were under option to and being prospected by the North State Pyrophyllite Company.

On the Richardson land, a short distance northeast of Major Hill and just west of State Road 2351, is an interesting occurrence of pyrophyllite. The outcrop area which is elongated in a northeast direction appears to be about 100 feet wide and 350 to 500 feet long. Both massive and radiating pyrophyllite are present.

About 2 miles east of Snow Camp and a short distance north of State Road 1005, the Carolina Pyrophyllite Company is quarrying sericite on a small ridge on a hill adjacent to the Foust lands. The sericite is being shipped by truck to Glendon where it is ground and blended with pyrophyllite. Open pit mining indicates a large tonnage of rock which may extend into the Foust lands to the north.

CHATHAM COUNTY

Hinshaw Prospect

The only known pyrophyllite deposits in Chatham County are on the farm of Don Hinshaw in the northwestern corner of the county. This property is about 2 miles east of State Road 1004 and a short distance north of State Road 1343. It can be reached by leaving State Road 1004 at State Road 1343 about 2.5 miles south of the Chatham-Alamance line. Follow State Road 1343 about 1.5 miles northeast to the Hinshaw farm. The outcrops are in a wooded area a short distance north of the Hinshaw home. Here, some years ago, Carolina Pyrophyllite Company opened a pit some 10 feet wide, 15 feet deep and 25 to 40 feet long. Near this pit, pyrophyllite is scattered through rocks over a distance of 100 feet long and 25 to 50 feet wide. To the northeast are other outcrops that look promising. Enough pyrophyllite outcrops are present in the area to indicate that it is worth prospecting.

RANDOLPH COUNTY

Pyrophyllite is known to occur in Randolph County in two areas. One of these is in the northeastern corner of the county about 3.5 miles west of Staley. The other is on the southern slopes of Pilot Mountain just north of State Highway 902 and about 8 miles east of Asheboro.

Staley Deposit

The Staley deposit, now worked out, was at one time the second largest pyrophyllite mine in the State. The main part of the deposit lay along the crest and northwest side of a rather steep hill as a lenticular body 100 to 200 feet wide and 350 feet long. The cleavage strike was approximately N. 50° E. and the dip was 60 to 70 degrees to the northwest. When abandoned the open cut was about 180 feet wide, 300 feet long and 250 feet deep. The hanging wall of the deposit consisted of a volcanic ash largely altered to a sericite schist. A central zone 10 to 150 feet thick contained a core of high grade massive to crystalline pyrophyllite 20 to 40 feet thick. The footwall was a massive high-silica rock about 60 feet thick. Quartz, sericite, pyrophyllite and chloritoid were prominent throughout the deposit. High alumina minerals were present in relatively small amounts. Andalusite was probably most abundant and locally formed aggregates of crystals several inches long. At depth the mineralized zone became too narrow to work and the deposit was abandoned. Over the years, pyrophyllite production amounted to approximately 400,000 tons.

Pilot Mountain Prospect

About 8 miles southeast of Asheboro, on the southern slope of Pilot Mountain, and a short distance north of State Highway 902, there are at least three outcrops of pyrophyllite on the Caddell land. The pyrophyllite occurrences are adjacent to an old abandoned road known as the John Wright road. The John Wright road begins at State Highway 902 a short distance east of State Road 2908 and continues in a northerly direction along the southern slope of Pilot Mountain. About one-half mile north of State Highway 902 and immediately along the east side of the John Wright road, pyrophyllite crops out as irregular masses of varying size over an area 100 to 150 feet wide and 200 to 300 feet long. The area of outcrop is elongated in a general northeast-south-

west direction. No prospecting has been done on this occurrence but it appears interesting.

About one-half mile to the north of the above described occurrence there is another deposit of pyrophyllite immediately along the west side of the John Wright road. Like the others, it has a northeast-southwest trend and from the outcrops present appears to be approximately 100 feet wide and 200 feet long. No prospecting has been done on this deposit but it appears interesting.

About midway between the two pyrophyllite occurrences described above, the John Wright road forks and what appears to be the main road continues in a direction a little north of west. Along this road between one-half and three-fourths of a mile from the forks, there are a number of old prospect pits immediately along the north side of the road. These old pits contain very little indications of pyrophyllite. However, about 1000 to 1200 feet almost N. 45° W. from these old pits is the north end of a northeast-southwest trending ridge that does contain considerable signs of pyrophyllite. Along this ridge for a distance of 1000 to 1500 feet radiating crystals of pyrophyllite associated with vein quartz are very abundant. No prospect pits are to be seen on the ridge but it has been explored by drilling. Details of this drilling are not available but reports are that the pyrophyllite is high in iron and mixed with considerable quartz. This is partly verified by the brown color of the pyrophyllite in outcrops and by the amount of quartz along the ridge. This ridge could contain pyrophyllite of value.

Due to a dense forest growth and the lack of abundant outcrops the geologic setting of the pyrophyllite deposits along the John Wright road is not definitely established. It appears, however, that these deposits are associated with acid fragmental rocks of volcanic origin.

MOORE COUNTY

Moore County contains the largest reserves of pyrophyllite known to occur in any locality in the United States. This mineral has been mined near Glendon for more than 100 years. Old grave stones in that vicinity show dates between 1840 and 1845 and according to Emmons (1856, p. 217) large quantities of pyrophyllite (agalmatolite) were ground the last year for the New York market.

What Emmons (1856, p. 52) regarded as agalmatolite and what is now known to be pyrophyllite was first thought to be soapstone. He stated: "A rock which occurs in extensive beds, and known in the localities where it is found as a soapstone, can by no means be placed properly with the magnesian minerals." He found the mineral to contain aluminum, classed it as agalmatolite and gave an analysis of agalmatolite and an analyses of soapstone for comparison.

There seems little doubt that the first attempts at pyrophyllite mining were made at what is now known as the Womble mine. This mine is located north of Glendon and about a mile from Hancock's Mill mentioned by Emmons. He stated (p. 53) "The first beds which I examined are at Hancock's Mill on Deep River." On page 54, he referred to "The agalmatolite, near Hancock's Mill and sometime called Womack's soapstone. . . ." On a map of the Deep River Coal Field at the end of his 1856 report, Emmons showed approximately at their correct locations, Hancock's Mill, the Womble home and soapstone. The name Womble has been known in the community for at least 100 years while the name Womack has not. As a result, it seems quite certain that the first mining near Hancock's Mill on Deep River was done at the mine known today as the Womble mine.

Deposits of pyrophyllite occur in 3 areas in Moore County as follows: (1) in a fault zone several miles long that lies along Deep River north of Glendon; (2) in a small area southwest of Hallison; and (3) in a fault zone several miles long that lies southwest of Robbins and along Cabin Creek. Eight pyrophyllite mines and prospects, three of which are being mined, are located on the Glendon fault from McConnell northeast of the county line. Other prospects opened on the Glendon fault to the northeast in Chatham County and southwest of the McConnell pit in Moore County have been abandoned for more than 40 years. Southwest of Hallison are three prospects that are currently idle. Two active mines and one idle prospect are located on the Robbins fault.

McConnell Prospect

The McConnell prospect is located approximately 0.5 of a mile northeast of the village of McConnell. McConnell is located south of High Falls and Deep River at the point where State Road 1487 intersects State Highway 22. Prospecting here originally consisted of an open cut about 400 feet long, 10 to 15 feet wide and 15 feet deep as

a maximum, which extended across the strike of the formations near the contact between acid tuff and a normal slate to the south. The pits are now almost completely filled up and grown over, but the dumps contain sericite schist, and foliated pyrophyllite. A highly sheared sericitized felsic tuff, in part silicified, is exposed along an access road west of the prospect. According to Conley (1962) the shear zone of the Glendon fault at this point is only about 40 feet wide and the mineralized zone approximately 10 feet wide.

Jackson Prospect

The Jackson prospect is located in a bend on the south side of Deep River some 2 miles north of the Norfolk Southern Railway, 3 miles northeast of the McConnell prospect and about 3 miles a little northwest of Glendon. The shear zone of the Glendon fault is about 200 feet wide in this area. The deposit is located on the fault zone in acid tuff near the contact with volcanic slate (bedded argillite) on the south. Two prospect pits have been opened to depths of 10 to 15 feet before the walls slumped. Considerable white foliated schist is exposed in the pits, but no commercial pyrophyllite was in sight when the pits were last visited.

Bates Mine

The Bates mine is located on the northeast bank of Deep River approximately 2 miles northeast of the Jackson prospect and 1.5 air line miles northwest of Glendon. Prospecting is reported to have been started in 1903. A mill was built in 1904 and operations continued until 1919 when the mine and mill were closed.

The development work done consists of two open cuts and a shaft on the footwall side and a large open cut on the hanging wall side of the property. The footwall consists of an acid volcanic breccia composed of fragments 1 to 2 inches in diameter. The hanging wall is a rhyolite somewhat sheared and weathered along the mineral body. The total width of the mineralized zone is between 150 and 300 feet along the zone of the Glendon fault.

On the footwall side and along the zone of breccia two open cuts were made, one on either side of a small stream about 600 feet east of the river. Each of these cuts was some 20 to 30 feet wide, 20 feet deep and 30 feet long. Small amounts of good pyrophyllite were found. Between these open cuts and the river a shaft was sunk to a depth of approximately 60 feet and drifts were run out. Small amounts of compact nonfoliated pyrophyllite are reported to have been found in this shaft.

On the hanging wall side, an open cut 250 feet long was made across the strike of the formations. At the north end of the opening another cut was opened at right angles to the first, the two combining in the shape of the letter "T". The width of the open cut was about 20 feet and the maximum depth about 40 feet. A drift was driven from the open cuts a short distance into the hillside. No commercial pyrophyllite was found in these openings. The operations were abandoned because of a lack of sufficient commercial material.

Attempts were made in the late 1920's and again in the 1930's to reopen the mine and activate the mill. Neither attempt developed sufficient pyrophyllite and the property has been idle since.

Phillips Mine

About 0.4 mile northeast along strike from the Bates mine and about 1.5 miles a little northwest of Glendon is the Phillips mine. It is separated from the Womble mine by State Road 1006 and lies to the southwest of that road. This property which is approximately 1500 feet long has approximately the same geologic setting as that of the Womble mine described below. The footwall is in part iron and in part acid volcanic breccia while the hanging wall is largely a medium to fine tuff which contains small amounts of rhyolite. The mineralized zone is 300 to 500 feet wide, but the best pyrophyllite is restricted to a zone 100 to 200 feet wide along the Glendon fault. Considerable mining has been done on this property in the past few years and an open cut 1200 feet long, 200 feet wide at places and 60 to 80 feet deep has been developed. The pyrophyllite, which is of the foliated variety, varies from white through yellowish, white to greenish in color, and has a well developed cleavage which strikes north 55 to 60 degrees east and dips from 45 to 70 degrees to the northwest. Quartz is present everywhere except in the very best pyrophyllite. Chloritoid is present along the footwall of the deposit but not as abundantly as in the Womble mine.

About 1902, a grinding mill was built on the southwest end of the property. This mill, which was of small capacity, was burned in 1927. In

1928, a modern grinding mill was erected on the Norfolk Southern Railway at Glendon. This mill which has been remodeled and improved several times since it was constructed is in use today.

Womble Mine

The Womble mine joins the Phillips mine along State Road 1006 and lies to the northeast. The pyrophyllite deposits on the Womble mine as outlined by pits and open cuts are about 1800 feet long and 500 feet wide. The pyrophyllite has a well developed cleavage which strikes north 55 to 60 degrees east and dips 45 to 70 degrees to the northwest.

The mineral body has been formed in acid volcanic tuff that varies from rhyolitic to dacitic in composition. The footwall, the full length of the deposit, is a volcanic breccia which in places is rich in iron, chiefly hematite. The amount of iron present makes the breccia look much like a low grade iron ore and for this reason it is commonly known as iron breccia. The hanging wall rock is a medium to fine-grained tuff with a small amount of rhyolite near the west end. On the footwall side and associated with the iron breccia is a large amount of dark green chloritoid. This mineral which appears as tiny grains 1 to 2 mm. in diameter passes by gradations into the pyrophyllite body and disappears in the pure pyrophyllite. The chloritoid is present in small amounts in the partly replaced rock masses in the pyrophyllite body and to a limited extent in the hanging wall rocks. Some of it has weathered to chlorite. Quartz is abundant in the deposit. It is present as irregular masses or nodules in the impure pyrophyllite and as large cherty or milky masses or nodules in the impure pyrophyllite and as large cherty or milky masses throughout the deposit. Quartz also occurs as small veins or stringers, some of which are parallel to the schistosity while a great many cut across the cleavage.

The pyrophyllite which is chiefly of the foliated variety varies from white, yellowish white, green, gray to almost black in color. The colors other than white are doubtless due to iron stain and should diminish with depth.

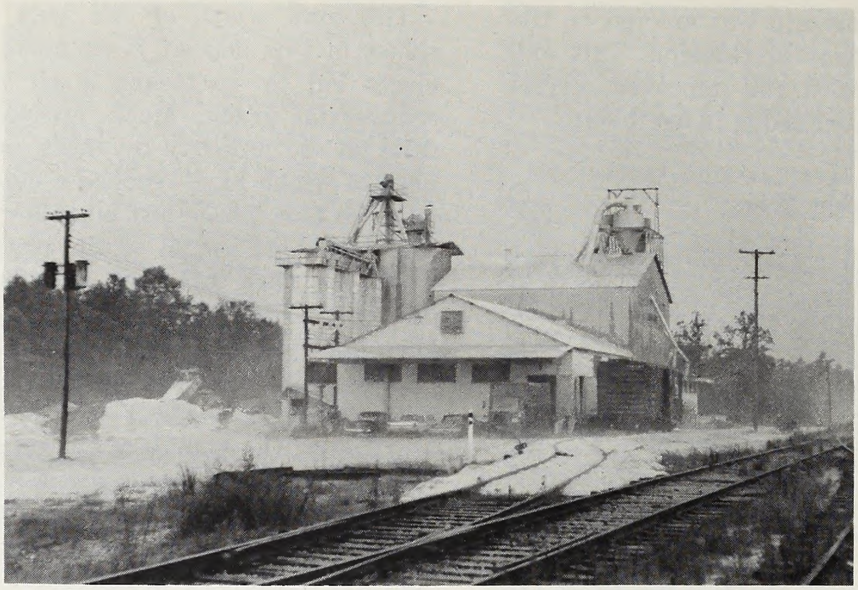
The deposit has a lenticular structure not only along strike but internally and down dip as well. Lenses of pure pyrophyllite occur along with lenses of quartz or lenses of only partly altered country rock.

The total width of the zone of pyrophyllite schist in this deposit is as much as 500 feet in places but by no means is all this material of commercial grade. Much prospecting has been done on the property by shaft, pit and open cut, none of which have reached a depth greater than 50 or 75 feet. These test pits show good pyrophyllite the whole length of the property. The most extensive work has been done on the northeast end of the deposit where a pit or quarry more than 400 feet long, 40 to 60 feet deep and 75 to 125 feet wide has been opened. Good material has been found throughout this pit. A similar pit, starting at the boundary of State Road 1006 and extending in a northeast direction, is found on the southwest end of the property. Recent mining in this pit has developed some very good pyrophyllite. The results of the prospecting done on this property indicate a body of commercial pyrophyllite 100 to 200 feet wide. Under the old methods of mining and milling not more than one-fourth of this was saved. With proper milling equipment it seems that most of the better grade material should go directly to the mill. The length and width of the mineralized zone indicate the presence of a large tonnage of pyrophyllite on this property.

Reaves Mine

The Reaves mine, first known as the Rogers Creek Mining Company property, then as the Snow prospect, and later as the White mine, is located on Rogers Creek about 2000 feet northeast of the Womble mine. According to Conley (1962a) "The ore body is contained between the Glendon fault on the southeast and a secondary reverse fault on the northwest." Prospecting by open cut has been carried out for a total length of approximately 2000 feet most of which is on the southwest side of Rogers Creek; recently, however, prospect pits have been extended a considerable distance northeast of Rogers Creek. The pyrophyllite body is lenticular in outline and has a cleavage that strikes northeast and dips at an angle of 60 to 70 degrees to the northwest.

The mineral body is found in an acid volcanic fragmental rock. The footwall is an acid volcanic breccia with fragments up to 3 or 4 inches in diameter. The hanging wall is a medium textured acid tuff. Chloritoid and chlorite are present in small amounts as minute grains. The pyrophyllite is yellowish to white in color and of the compact



A. Mill

B. Open Pit Mine
(Reaves)

Plate 3. Glendon Pyrophyllite Company

foliated variety. Some of the best pyrophyllite shows the fragmental texture which was characteristic of some of the original rock before replacement.

Pyrophyllite has been exposed in an open cut along strike for some 500 feet. The northeastern end of this pit near Rogers Creek is about 150 feet wide at the top and 50 to 60 feet deep. Both northeast and the southwest of this well developed part of the open cut all the indications point to promising amounts of good pyrophyllite. This property appears to contain a large body of pyrophyllite.

Jones Prospect

A little more than a mile northeast of the Reaves mine is the Jones prospect which was opened on land formerly belonging to the late A. J. Jones but now reported to be a part of the Hancock estate. An open cut about 100 feet long and 2 to 6 feet deep was opened on the northeast slope of a small hill, just above a small stream. The few surface exposures present indicate that the rock in this area is highly sheared. Good pyrophyllite, somewhat foliated and discolored, and masses of sericite schist containing chloritoid are to be seen along this pit. The size of the deposit could not be determined from the amount of prospecting done. Enough can be seen to indicate that the prospect may have promise of becoming an important producer of pyrophyllite.

Currie Prospect

About one-half mile northeast of the Jones prospect and near the point where State Road 1620 crosses the county line, prospecting for pyrophyllite was done on the farm of C. L. Currie several years ago. When first opened the pits showed some signs of pyrophyllite, but now they are more or less filled up and overgrown to the extent that little or no pyrophyllite can be seen. It will take considerable prospecting to determine if pyrophyllite of value is present at this locality.

Ruff Prospect

The Ruff prospect, according to Conley (1962a) is located about 1.5 miles southwest of Hallison. The mineralized zone averages from 6 to 15 feet wide at the center, but narrows to the northwest and southeast, and finally dies out along strike in these directions. The mineralized zone which can be traced for about 180 feet occurs in a fault zone which strikes N. 20° E. and dips northwest at about 80 degrees. The southeastern limb of the deposit is displaced to the northwest by a cross fault which strikes N. 45° W. and dips to the northeast at about 75 degrees.

Hallison Prospect

Less than a mile southwest of Hallison is a small body of pyrophyllite schist that was discovered while prospecting for gold. At this point, several shallow pits have been dug along a quartz vein. The rock in contact with the quartz is a sericite schist containing varying amounts of pyrophyllite. The prospect is located in the shear zone of a northeast trending fault in felsic tuffs. The prospect pits do not reveal the presence of much pyrophyllite but the geologic setting is correct for a workable deposit.

Standard Mineral Company

Beginning about 1.5 miles southwest of Robbins on Cabin Creek and continuing in a southwest direction for a distance of some 5 miles is a band or zone of pyrophyllite on which the most important mine in the State is located. The rocks along this zone consists of an acid volcanic tuff. The strike varies from N. 35° to 40° E. and the dip varies from 50 to 70 degrees to the northwest. Pyrophyllite schist crops out at a number of points along this zone but only two deposits are known to be of commercial value at present.

The property of the Standard Mineral Company is located about 2.5 miles southwest of Robbins and about 1.5 miles south of the Norfolk Southern Railway. Pyrophyllite is said to have been discovered on this property about 1888 when in the course of gold mining operations a drift was driven into a hillside. The vein encountered at that time was only about 10 feet wide and little effort was made to work it. In 1918, Mr. Paul Gerhardt gave a neighbor permission to haul cross ties across his property. The wagon wheels brought up a fine white material which proved to be pyrophyllite, from a zone of pyrophyllite and pyrophyllite schist some 150 feet wide.

During 1919 some pyrophyllite was mined from open cuts and shipped to Charlotte for grinding. This did not prove economical and in 1920 a shaft was sunk to a depth of 90 feet on a lens of pyrophyllite about 14 feet wide and a small grinding mill was built on the property. Under-

A. Mill

B. Open Pit Mine

Plate 4. Standard Mineral Company

ground exploration and development work showed that to the northwest there was a body of pyrophyllite 30 feet wide. About 1925 a shaft 200 feet deep was sunk in barren ground adjacent to this 30 foot vein of pyrophyllite and a more modern grinding mill was built. Later a modern two compartment shaft was sunk to a depth of 650 feet in the footwall of the deposit at a point some 700 feet northeast of the first two shafts, and a modern grinding mill was built on the Norfolk Southern Railway 1.5 miles away. This shaft and mill are currently being used in mining and grinding pyrophyllite.

This pyrophyllite body as it is known today begins on Cabin Creek just south of the old Cagle gold mine and extends southwest for a distance of nearly a mile. The most important part of this body is on the southwestern end and consists of some 2000 feet along the surface. The mineralized zone is about 200 feet wide and lies along the Robbins fault in a zone of complicated reverse faulting. In places this faulting has repeated the pyrophyllite zone, making the minable pyrophyllite body as much as 150 feet wide. The northeastern half of the deposit is offset to the northwest by cross faulting.

The deposit occurs in a medium to fine-textured felsic tuff which has been strongly sheared and possesses a well defined cleavage which strikes N. 20° to 30° E. and dips from 50 to 70 degrees to the northwest. Underground operations show the hanging wall to consist of 75 to 100 feet of silicified tuff grading into an unaltered tuff. On the footwall side, the rock consists of a silicified tuff about 110 feet wide which gradually grades into an unaltered tuff. For a number of years, mining has been carried out both by underground and open pit operations. The pyrophyllite taken from this mine is in general of a high quality. The impurities consists of small lenses of silicified tuff and numerous small quartz veins. Varying amounts of sericite and an occasional grain of chloritoid are found around the borders of the deposit.

Tucker and Williams Pits

The Tucker and Williams pits are located on the Robbins fault about two miles southwest of the mine of the Standard Mineral Company. Pyrophyllite is exposed in both pits which are about 500 feet apart. The Tucker pit is on the north and the Williams pit is on the south. Pyrophyllite has been developed in both pits along two parallel shear zones some 20 to 25 feet wide. Good grade pyrophyllite is exposed in the shear zones, while the material bordering the good pyrophyllite is a highly siliceous sericite schist that is badly iron stained. The shear zones and the cleavage in the pyrophyllite strike N. 30° to 35° E. and dip steeply to the northwest. The pyrophyllite bodies exposed in the southern pit lie to the northwest of the strike of those in the northern pit, indicating that the mineralized zones have been offset by cross faults. The country rock is a highly silicified and sericitized fine-grained felsic tuff that has been badly crushed and sheared.

Sanders Prospect

About 5 miles southeast of Star and a few hundred feet from the point where Cotton Creek enters Cabin Creek, on a farm formerly owned by Mrs. Bettie Sanders but now the property of Harry Lemons, is an outcrop of pyrophyllite that can be traced for about 800 to 1000 feet along the surface. Pyrophyllite is found, about 500 feet west from the house, on a prominent ridge that extends back from the creek 500 to 800 feet in a northeast direction.

The country rock is a medium to fine textured, felsic volcanic tuff with a well developed cleavage which strikes N. 30° E. and dips 40 to 50 degrees to the northwest. Numerous small quartz veins cut the country rock at all angles. Associated with these small quartz veins and scattered through the country rock are varying amounts of pyrophyllite, chiefly of the radiating variety. Small amounts of flake and foliated pyrophyllite are also present. In 1922 the writer collected some excellent specimens of radiating pyrophyllite from a small pit on the southeast slope of the hill. Associated with this pyrophyllite were veins of diaspore 2 to 3 inches thick. The old pit has been filled up and is grown over and no longer available for collecting.

On the point of the ridge to the southwest end of the property near the creek are two old pits. These pits which are some 5 to 10 feet deep and 10 feet long are said to have been gold prospects. Both show small amounts of pyrophyllite which is of the radiating variety and badly iron stained. On the southwest slope of the hill, just above the creek, is a trench 2 or 3 feet deep and 150 feet long that trends in a N. 20° W. direction. This trench shows very little pyrophyllite.

MONTGOMERY COUNTY

Ammons Mine

Pyrophyllite deposits that have been prospected and/or mined occur at 5 localities in Montgomery County. One of these known as the Ammons mine is located in the northeast corner of the county a short distance southeast of Asbury on U.S. Highway 220 to State Road 1340 which is also marked, "Mine Road." Follow "Mine Road" about one-half mile to the corner of a field where two unimproved roads may be seen. One of these leads in a direction a little east of south and ends at a distance of about 2500 feet at the Ammons mine.

The Ammons mine, now worked out and abandoned, consists of an open cut approximately 1500 feet long that strikes in an over-all direction of about north 40 degrees east, and varies in depth from 10 to 25 or 30 feet. All indications are that a fair amount of good pyrophyllite, highly foliated, was obtained from this mine. The pyrophyllite appears to have occurred as lenses 1 to 3 feet wide and 10 to 15 feet long associated with a cherty to siliceous rock. Before mineralization this rock was a normal felsic tuff of volcanic origin. At least the rock surrounding the mine pit is a felsic fragmental material of volcanic origin.

The only good pyrophyllite seen on this property is a lense of undetermined width and about 50 feet long that is partly exposed in the bank of a small stream at the northeast end of the open cut. Nothing was seen to indicate why this lens was left undisturbed.

North State Property

About 1500 feet along strike to the northeast of the Ammons mine is a pyrophyllite deposit 75 to 200 feet wide and 1000 to 1200 feet long that is owned by North State Pyrophyllite Company. It may be reached by following "Mine Road" about one-half mile from its intersection with U. S. Highway 220 to the corner of a field, and then taking an unimproved road that leads in a direction a little south of east. This unimproved road ends at the deposit which is about 1500 feet from "Mine Road."

The deposit is in the form of a ridge that rises 20 to 40 feet above the elevation of the surrounding countryside and trends in a north 40 degrees east direction. The ridge contains four knobs or knob-like masses 75 to 150 feet wide and 150 to 250 feet long that rise to elevations of 10 to 20 feet above the remainder of the ridge. These knobs are composed largely of good pyrophyllite. Rock outcrops are not abundant in the sags between knobs but those found were composed largely of good pyrophyllite.

The property has been core drilled but records of the holes are not available. A marker at one hole indicated a depth of 50 feet. If as indicated from the outcrops available, this ridge contains good pyrophyllite throughout its length and the pyrophyllite extends to a depth of 50 feet below the general surface, the deposit contains a large tonnage of good material. The impurities observed were limited amounts of chloritoid, some vein quartz and some iron stain which appears to be most abundant near some old pits and shafts that were dug during prospecting for gold.

North State Property 2

About three miles southeast of Abner is another interesting deposit of pyrophyllite that was prospected to a limited extent several years ago by North State Pyrophyllite Company. This deposit may be reached by starting at the point where State Road 1312 crosses 1311. From this point follow State Road 1312 south for a distance of seven tenths of a mile to an unimproved road. Follow this road for three tenths of a mile in a southeast direction to a quartz ridge that shows signs of having been prospected. Then follow the quartz ridge in a general northeast direction to a prominent hill.

This hill trends about north 40 degrees east, has a maximum width of about 300 feet, a length of between 400 and 500 feet and rises more than 50 feet above the general elevation of the surrounding countryside. This hill contains some unaltered rock but appears to consist largely of pyrophyllite. A prospect pit or quarry was started some years ago on the northwest side near the foot of the hill and developed at right angles to the strike of the cleavage of the pyrophyllite, for a distance of about 20 feet, all in good pyrophyllite. Had the quarry been continued to the center of the hill a quarry face at least 40 to 50 feet high would have been developed. The pyrophyllite contains an excessive amount of chloritoid which apparently accounts for not developing the deposit. Except for excessive chloritoid this is a promising deposit of pyrophyllite.

Cotton Stone Mountain

Cotton Stone Mountain is located about 4 miles almost due north of the center of Troy and less than one-half mile west of State Road 1312. Pyrophyllite has been known to occur in the general vicinity of Troy since Emmons published his "Geological Report on the Midland Counties of North Carolina" in 1856. Many textbooks also carry references to pyrophyllite on Cotton Stone Mountain.

This mountain is a prominent hill that rises gradually to a height of some 200 feet above the neighboring stream valley. The hill consists of two prominent points or knobs with a sag between them, producing a saddle. The country rock is an acid volcanic tuff with a definite cleavage that strikes north 45 to 55 degrees east and dips 50 to 70 degrees to the northwest. Numerous quartz veins are found throughout the mountain.

Pyrophyllite, chiefly of the radiating variety, occurs abundantly on this hill. The numerous quartz veins present have made mining of this pyrophyllite uneconomical. The mineral body is elongated in a northeast-southwest direction with a length of some 1500 to 2000 feet. On the southwest, and more prominent point of the hill, two or three prospect pits have been dug, presumably for gold as they are all along quartz veins. In these pits and on the dumps much pyrophyllite may be seen all of which is badly iron stained. The excessive quartz and great amount of iron stain have apparently discouraged prospecting for pyrophyllite on Cotton Stone Mountain.

Standard Mineral Company

Standard Mineral Company is developing a promising pyrophyllite deposit about 1.5 miles northwest of Wadeville. This deposit may be reached by going west of Wadeville on State Road 1134 to the intersection with State Road 1135, and then north along State Road 1135 a distance of seven-tenths of a mile to a private road that leads about north 45 degrees west, a distance of about three-fourths of a mile and ends at the deposit.

The country rock of the region is a felsic fragmental rock of volcanic origin. The pyrophyllite deposit as explored is about 300 feet wide and 500 feet long. The pyrophyllite and enclosing rocks have a cleavage that strikes about north 40 degrees east and dips steeply to the northwest. The deposit appears to contain a high percentage of good pyrophyllite. A small amount of chloritoid is associated with the pyrophyllite and some quartz veins are also present. The pyrophyllite varies from massive to foliated, with the foliated variety being more abundant. Near the north end of the deposit, as now developed, there is some red clay present as one or more zones in otherwise good pyrophyllite. On the footwall side near the northeast end of the body is some very pure sericite. This is a promising deposit that appears to contain a large tonnage of high-grade pyrophyllite.

REFERENCES CITED

Bowman, F. O., 1954, The Carolina Slate Belt near Albemarle, North Carolina: Unpublished dissertation for the Degree of Doctor of Philosophy, University of North Carolina Library, 85 pp.

Buddington, A. F., 1916, Pyrophyllitization, pinitization, and silicification of rocks around Conception Bay, Newfoundland: Jour. Geol. Vol. 24, pp. 130-152.

Brush, G. J., 1862, Description and analyses of pyrophyllite from North Carolina: Am. Jour. Sci. Ser. II, Vol. 34, p. 219.

Clapp, C. H., 1914, The geology of the alunite and pyrophyllite rocks of Kyuquot Sound, Vancouver Island: Summary Report of the Geological Survey, Dept. of Mines for 1913, pp. 109-126.

Clark, F. W., 1920, Data of geochemistry: U.S. Geol. Survey Bull. 695, pp. 615-616.

Conley, J. F., 1959, Geology of the Albemarle quadrangle, North Carolina: (abstract) Geol. Soc. Amer. Bull., Vol. 70, No. 12, Part 2, p. 1760.

——————, 1962a, Geology and mineral resources of Moore County, North Carolina: N.C. Dept. Conservation and Development Bull. 76, 40 pp.

——————, 1962b, Geology of the Albemarle quadrangle, North Carolina: N.C. Dept. Conservation and Development, Bull. 75, 26 pp.

——————, and Bain, G. L. 1965, Geology of the Carolina Slate belt west of the Deep River-Wadesboro Triassic basin: Southeastern Geology, Vol. 6, No. 3, pp. 117-138.

Dana, E. S., 1909, A system of mineralgy, p. 691.

Diller, J. S., 1899, Origin of Paleotrochis: Am. Jour. Sci. Ser. 4, Vol. 7, pp. 337-342.

Emmons, Ebenezer, 1856, Geological report of the midland counties of North Carolina: N.C. Geological Survey, Henry I. Turner, Raleigh, 351 pp.

Espenshade, G. H., and Potter, D. B., 1960, Kyanite, sillimanite and andalusite deposits of the southeastern states: U.S. Geol. Survey Prof. Paper 336, 121 pp.

Graton, L. C., 1906, Reconaissance of some gold and tin deposits in the southern Appalachians: U.S. Geol. Survey, Bull. 293.

Gruner, J. W., 1934, The crystal structure of talc and pyrophyllite: Am. Mineralogist, Vol. 19, pp. 537-576.

Hafer, C., 1913, Pyrophyllite in North Carolina: Eng. and Min. Jour. Vol. 96, p. 623.

Hendricks, S. B., 1938, On the crystal structure of talc and pyrophyllite: Zeitschr. Kristallographie, Band 99, pp. 264-279.

Jahns, R. H., and Lance, J. F., 1950, The San Dieguito pyrophyllite area San Diego County California: California Division of Mines, Special Report 4, 32 pp.

Kerr, W. C., 1875, Report of the geological survey of North Carolina physical geography, resume, economical geology: N.C. Geol. Survey, Vol. 1, 325 pp.

____________, and Hanna, G. B., 1893, Ores of North Carolina, Chapt. 2, Vol. 2, Geology of North Carolina by W. C. Kerr, Raleigh, Edwards and Broughton.

Laney, F. B., 1910, The Gold Hill mining district of North Carolina: N.C. Geol. and Econ. Survey, Bull. 21, 137 pp.

____________, 1917, The geology and ore deposits of the Virgilina district of Virginia and North Carolina: N.C. Geol. and Econ. Survey, Bull. 26, 176 pp.

LeChatelier, M. H., 1887, De L'Action de la Chaleur sur les Argiles: Bull. Soc. Min. France, Vol. 10, p. 207.

Levy, M., and Lacroix, A., 1888, Mineraux des Roches, 254 p.

Lindgren, W., 1919, Mineral deposits: McGraw-Hill Book Co., New York, pp. 478-480 and 549-564.

Manasse, E., 1910, Cloritoide (ottrelite) delle Alpi Apuane: Mem. Soc. Tosc. Vol. 26, pp. 121-142.

Niggli, P., 1912, Die Chloritoidschiefer und die sedementaren zone am Nordstrande des Gottordmassines: Beritrage zur Geologischen Karte der Schweiz, Vol. 36, 1912.

Nitze, H. B. C., and Hanna, G. B., 1896, Gold deposits of North Carolina: N.C. Geol. Survey Bull. 3.

Nockolds, S. R., 1954, Average chemical compositions of some igneous rocks: Geol. Soc. Amer. Bull., Vol. 65, pp. 1007-1032.

Olmsted, D., 1822, Descriptive catalogue of rock and minerals collected in North Carolina: Am. Jour. Sci. Ser. I, Vol. 5, pp. 257-264.

____________, 1825, Report on the geology of North Carolina conducted under the Board of Agriculture, J. Gale and Son, Raleigh, 48 pp.

Pogue, J. E., 1910, Cid mining district of Davidson County, North Carolina: N.C. Geol. and Econ. Survey Bull. 22, 141 pp.

Powers, F. D., 1893, The Pambula gold deposits: Quart. Jour. Geol. Soc., Vol. 49, pp. 232-235. Bauerman H. statement at the end of Power's paper.

Pratt, Joseph Hyde, 1900, Talc and pyrophyllite deposits in North Carolina: N.C. Geol. Survey Econ. Paper 3.

Rogers, A. F., 1916, Sericite as a low temperature hydrothermal mineral: Econ. Geol., Vol. II, pp. 118-150.

Ross, C. S., and Hendricks, S. B., 1945, Minerals of the montmorillonite group: U.S. Geol. Survey Prof. Paper 205-B, pp. 70-71.

St. Jean, Joseph, Jr., 1964, New Cambrian trilobite from the Piedmont of North Carolina: Geol. Soc. Amer. Special Paper, 82.

Stromquist, A. A., and Conley, J. F., 1959, Geology of the Albemarle and Denton quadrangles, North Carolina: Field trip guidebook, Carolina Geological Society, 36 pp.

Stuckey, J. L., 1928, The pyrophyllite deposits of North Carolina: N.C. Dept. Conservation and Development Bull. 37, 62 pp.

Vanderbilt, R. T. Co., 1943, Pyrophyllite, New York, 24 pp.

Vhay, J. S., 1937, Pyrophyllite deposits of Manuels, Conception Bay district: (abstract) Econ. Geol., Vol. 32, pp. 1076-1077.

Watson, T. L., and Powell, S. L., 1911, Fossil evidence of the age of the Virginia Piedmont Slates: Am. Jour. Sci. Ser. IV, Vol. 31, pp. 33-44.

Weed, W. H., and Watson, T. L., 1906, The Virgilina copper district: Econ. Geol., Vol 1, pp. 309-330.

White, A. M., Stromquist, A. A., Stern, T. W., and Westly, H., 1963, Ordovician age for some rocks of the Carolina Slate Belt in North Carolina: U.S. Geol. Survey Prof. Paper 475-C, pp. C107-C109.

Williams, G. H., 1892, The volcanic rocks of South Mountain in Pennsylvania and Maryland, Am. Jour. Sci. Ser. III, Vol. 44, pp. 482-496.

____________, 1894, The distribution of ancient volcanic rocks along the eastern border of North America: Jour. Geol., Vol. 2, pp. 1-31.

Zen, E-an, 1961, Mineralogy and petrology of the systems Al_2O_3 — SiO_2 — H_2O in some pyrophyllite deposits of North Carolina: Am. Mineralogist, Vol. 46, pp. 52-66.